RESEARCH ON THE PREVENTION OF WORK-RELATED MUSCULOSKELETAL DISORDERS

STAGE 1 - LITERATURE REVIEW

2006

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This report was commissioned by the Department of Employment and Workplace Relations on behalf of the Australian Safety and Compensation Council and was undertaken by Associate Professor Wendy Macdonald and Associate Professor Owen Evans from La Trobe University.

Department of Employment and Workplace Relations

OHS EXPERT RESEARCH PANEL

Research on the Prevention of Work-Related Musculoskeletal Disorders Stage 1 – Literature Review

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EXECUTIVE SUMMARY

The purpose of the present report is to summarise contemporary research literature and other documented evidence concerning:

1. hazards that are most strongly predictive of the risk of work-related musculoskeletal disorders (WMSDs)
2. currently available WMSD risk management methods – including methods of identifying hazards and assessing risk levels, and general means of risk control
3. evidence concerning real or perceived barriers to the implementation of risk assessment and control measures.

This task constitutes the first part of a planned multi-stage project, the overall purpose of which is to develop and trial more effective risk management methods for work-related musculoskeletal disorders (WMSDs), particularly those that develop cumulatively.

Literature search strategies are described in Section 2 of the report. A review of all primary sources of information on this topic was beyond the scope of this report since the project timeframe was very short in relation to the very large literature on this topic.

Addressing the first of the above aims, evidence identifying the main hazards or causal factors for WMSDs is reviewed in the first part of Section 3. Conclusions are summarised in the form of an evidence-based conceptual framework, depicted in Figure 6. It is shown that cumulative WMSDs can stem from a wide range of factors that together result in an inadequate margin between people's work demands and the coping resources available to them. These WMSD hazards are listed below.

Hazardous task and job demands:

– Hazards related to the physical characteristics of task performance – particularly awkward or sustained postures, repetitive movements, static and dynamic loads or force exertions, hand-arm vibration, local tissue compression
– Excessive amounts of work, long shifts, inadequate rest breaks, long weeks, time pressures, responsibilities, etc
– Inadequate time to cope with perceptual/ cognitive task demands
– Excessive emotional demands of the work

Inadequate resources for coping with work demands:

– Inadequate workplace support: poor materials/information, poor supervisor support, poor social cohesion, low morale, inadequate training provisions

– Physical environment hazards: whole-body vibration, cold

Other psychosocial hazards, such as:

– Inadequate personal control and autonomy
– Inadequate task variety and opportunities for skill utilization
– Inadequate job security

Low levels of individual resources in relation to task or overall job requirements: biological tolerances, inadequate skills and/or basic capacities or skills

Resultant hazardous personal state(s) of fatigue (varying types) and/or of psychological stress which entail physiological responses that directly increase injury risk.

The above factors, whether singly or in combination, can result in hazardous personal states such as high levels of fatigue (of varying types) and/or of psychological stress, which entail *physiological* responses that directly increase injury risk; these states can also induce *behavioural* changes which increase risk. In addition, hazardous task and job demands, particularly their physical components, can directly increase the risk of acute-onset WMSDs (although these are not the primary focus of the present report). Following identification and discussion of these various WMSD hazards and risk factors, the final part of Section 3 reviews the kinds of risk control strategies that are required.

Section 3 also includes an evaluation of the adequacy of current evidence that WMSDs are indeed *work*-related; its adequacy is confirmed. It also reviews evidence concerning the relative influence of physical versus psychosocial hazards on WMSD risk. Although their relative influences are variable, depending on a wide range of factors, it is now well established that *both* can have a substantial influence. There is also some evidence that at least some physical and psychosocial hazards can act synergistically in increasing WMSD risk, but such interactions are inadequately understood and there is a need for more research on this topic. It is concluded that it is no longer appropriate for psychosocial hazards to be seen as necessarily secondary or peripheral to physical hazards for WMSDs – particularly in light of the accumulating evidence of biological pathways via which they can be *directly* involved in the development of injury. In many documented situations, WMSD risk has been shown to be highest when *both* physical and psychosocial hazard levels are high.

Addressing the second of the aims, Section 4 critically evaluates WMSD hazard identification and risk assessment methods that are suitable for use by non-experts in ordinary workplaces (or that have apparent potential to be amended to meet this requirement). The most commonly used methods appear to be *hazard identification* checklists such as those from one of the Manual Handling Codes, suggesting that very little formal *risk assessment* occurs in most Australian workplaces – notwithstanding that the process of hazard identification and risk control using one of the common checklists is widely referred to as "manual handling risk assessment".

Reviewing the overall balance and comprehensiveness of coverage of hazard assessment methods, it is found, unsurprisingly, that physical hazards are addressed much more commonly and comprehensively than are psychosocial hazards – whether those stemming from the work, job and workplace environment, or hazardous personal states of fatigue or stress. Focusing just on the *physical* hazards addressed by current methods, it is evident that dynamic load and whole-body posture are the most common focus of attention. Fewer methods are available to assess the degree (as opposed to simply identifying the presence) of risk associated with highly *repetitive movement* patterns, awkward *wrist postures* and *hand activities*. Further, while *sustained* postures and *static* loads are sometimes included on checklists, they are seldom assessed; and the situation is even worse in the case of risk due to high angular *velocities* of trunk bending and rotation, which is rarely even mentioned on checklists. Finally, the possible role of *vibration* – whether whole-body or hand-arm – is often given some cursory mention but rarely assessed. This overall imbalance in the content of both WMSD hazard identification checklists and risk assessment methods indicates that these methods lag substantially behind current research evidence of the nature of WMSD hazards and associated risk levels.

Risk assessment requires consideration of hazard exposure *durations,* as well as hazard *severity* at a specific point of time (when assessed), because risk is likely to depend on the *total dose* to which workers are exposed, particularly in the case of cumulative injuries. However, most WMSD assessment methods measures give just a brief 'snapshot', giving greater weight to the observed severity at just one (or a few) observed points in time than to exposure duration or overall dose.

Overall, it is concluded that the deficiencies in existing methods of WMSD hazard identification and more particularly, risk assessment, present a significant barrier to achieving more effective risk management.

Addressing the third aim, evidence concerning barriers to the implementation of effective WMSD control measures is reviewed. Little published evidence was available, but the following kinds of barrier are tentatively identified. First, use of the term 'manual handling' injuries as a label for WMSDs is in itself a significant barrier to more effective risk management, particularly when the term is used to label the standards, codes and guidance documents that for most people are the primary means of controlling WMSDs. Use of such terminology constrains people's thinking about possible causes of WMSDs and results in much too narrow a concept of how WMSD risk should be managed.

Second, there is evidence of a widespread failure to adopt a broad and integrated 'systems' approach to risk management, resulting in a piecemeal approach to risk management in which the focus of most WMSD hazard identification, risk assessment and control methods is on specific *tasks*, whereas cumulative exposure or dose is determined by workers' overall *jobs*. In the absence of such an approach, there is no reliable basis for identifying the kinds of control measures likely to be most effective. Third, and related to the previous point, there appears to be inadequate adherence to the 'hierarchy of risk control', with too great a reliance on interventions such as training in 'safe lifting' techniques. Finally, poor usability of risk management information and methods is arguably an additional reason for poor risk management practices, since managers' knowledge and understanding of occupational health and safety risk management principles appears to be generally poor. In this context, it is hypothesised that to support good understanding and usability for non-expert users, risk *assessment* methods must to some degree be adapted, as many *hazard identification* checklists have already been, to more directly match the kind of work and work environments where they are intended to be applied. One of the aims of the proposed second stage of this project is to investigate this issue.

The above findings confirm the importance of proceeding to Stage Two of this project, where the focus will be on the development and evaluation of WMSD risk assessment methods that are usable by non-experts and that address a full range of hazards within the high-risk industry sectors targeted.

1. INTRODUCTION

1.1 Context and aims of the report

This report documents the first stage of a planned multi-stage project, the purpose of which is to develop and trial more effective risk management methods for work-related musculoskeletal disorders (WMSDs).

The primary purpose of the report is to establish the basis for the second stage of the project, which will entail formulation and implementation of procedures to assess those physical and psychosocial hazards that are most strongly predictive of WMSD risk – particularly the risk of cumulative injuries associated with repetitive movements or static postures. That work will be conducted in collaboration with industry partners in a sample of workplaces drawn from high risk industry sectors. Within the specific contexts of those workplaces, the nature of current risk control measures will be documented and any barriers to the implementation of additional controls that are identified as potentially useful will be determined.

Accordingly, the aims of the present report are to review and summarise contemporary literature and other documented evidence on:

1. the main physical and psychosocial hazards related to the various injury mechanisms for body stressing injuries as categorised in the National Data Set
2. current hazard identification and risk assessment tools and practices, and management practices to reduce the risk of WMSDs; and
3. evidence concerning real or perceived barriers to the implementation of risk assessment and control measures.

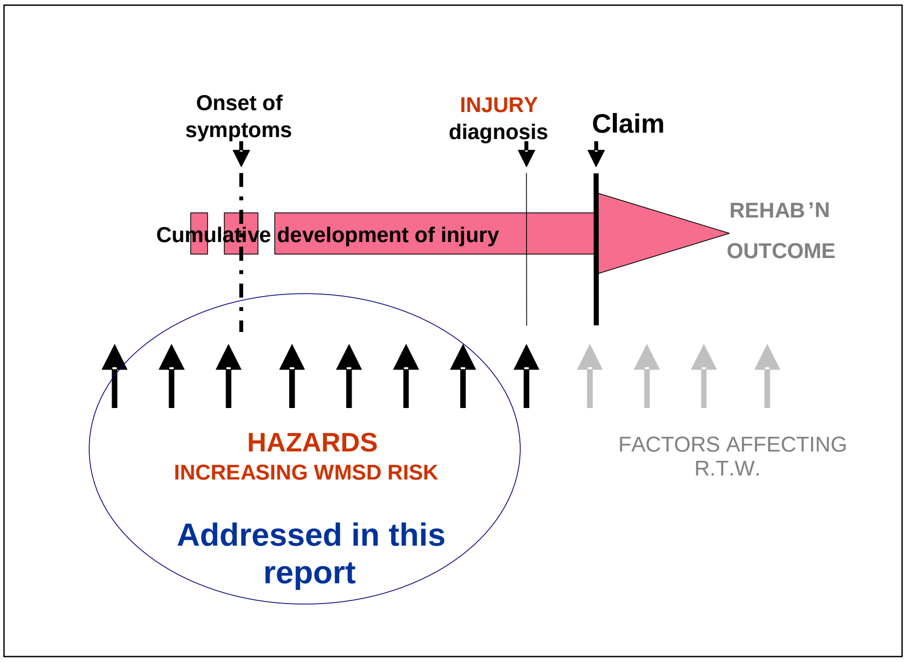
The first of these aims is necessary to ensure that the set of hazard assessment methods to be formulated for Stage Two have adequate construct validity; that is, to ensure that all significant hazards are addressed. The second of the above aims relates most directly to the primary purpose of the project: to identify the most promising set of hazard assessment methods and associated risk control strategies. The third aim is included because the use of appropriate methods of risk assessment and the identification of potential risk control methods is not in itself sufficient to achieve subsequent reductions in injury risk. It is *also* necessary for the control measures identified to be practicable for *implementation;* accordingly, evidence concerning factors that may inhibit this last, crucial step in the risk management process is reviewed.

1.2 Scope of the report

Section 2 describes the method and processes followed in reviewing research literature and other relevant documents. Then Section 3, on *Evidence Identifying Main Hazards,* starts with a summary of current knowledge concerning the main hazards or causal factors for WMSDs. A review of all primary sources of information on this topic was beyond the scope of this report, since the literature is now huge and the project timeframe was very short. The references are drawn mainly from several recent and comprehensive reviews of literature covering this domain, supplemented by recent reports on more specific topics where these were considered to add something substantive. The focus of the literature search strategy on this topic was therefore on recent reports that might modify or extend substantively the currently established body of knowledge.

As depicted in Figure 1, the hazards addressed are those relevant to primary prevention (reducing hazards entirely proactively) and secondary prevention (reducing hazards in response to evidence indicating injury precursor states or early symptoms of injury). This report does not address issues that pertain specifically to rehabilitation – i.e. the 'tertiary prevention' phase.

Figure 1. The hazards addressed in this report are those related to *primary and secondary prevention*; not to rehabilitation.



These types of hazard cover the full gamut of those that are now established as important for WMSD prevention – both physical and psychosocial. Figure 2 depicts the roles of both types of hazard in contributing to cumulative tissue damage that increases the risk of WMSDs.

Figure 2. A model highlighting evidence that it is not only physical hazards that increases the risk of WMSDs; psychosocial hazards such as excessive workloads can precipitate a 'stress response' that also entails changes to internal physiological functioning which increase WMSD risk.

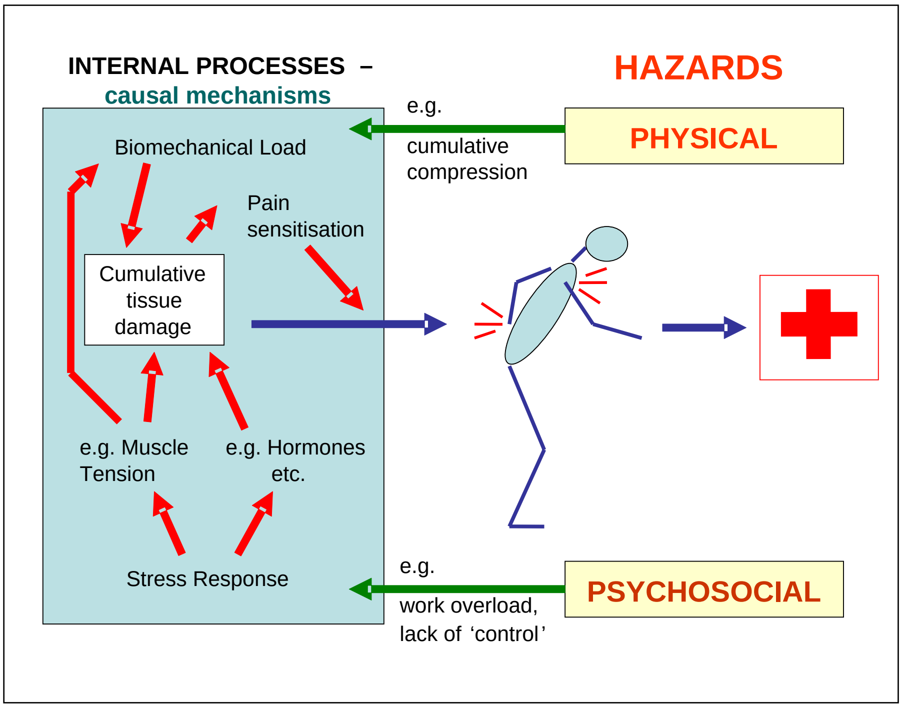
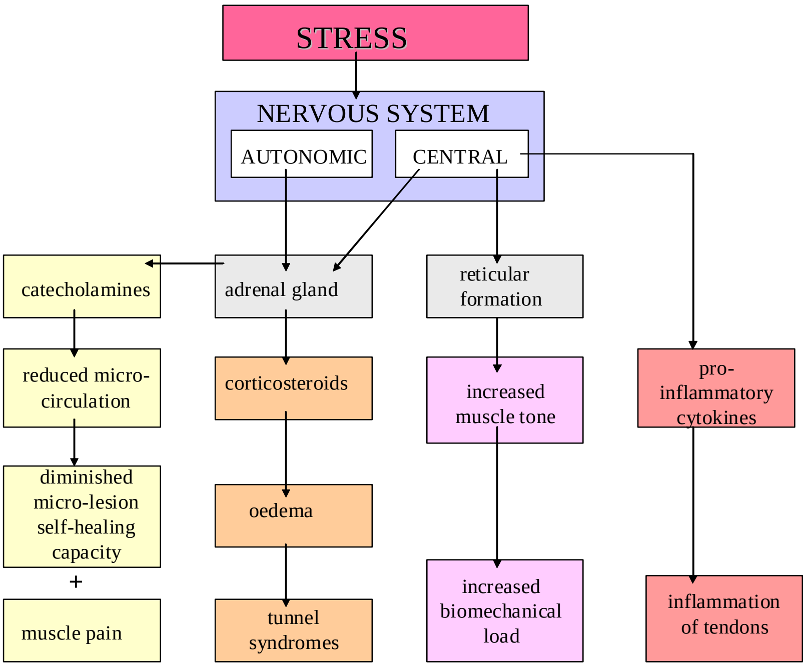


Figure 3. Probable relationships between some physiological components of the stress response and WMSD symptoms (adapted from Aptel and Cnockaert, 2002).



Because there is resistance in some quarters to accepting the importance of psychosocial factors as WMSD hazards, it is worth briefly identifying here some of the proposed physiological mechanisms via which elements of the 'stress response' can directly increase the risk of WMSDs. At a general level, Belkic and colleagues (Belkic et al, 2000) argue that the stress response can cause dysregulation of the autonomic nervous system and the hypothalamic-pituitary-adrenocortical axis. Some of the pathways via which such effects could affect WMSD risk are depicted in Figure 3, which is adapted from the model of Claudon and Cnockaert (1994; in Aptel and Cnockaert, 2002); this depicts four pathways by which different physiological dimensions of the stress response can directly increase MSD risk. First, stress is often associated with changes in catecholamine levels (for example, adrenaline, noradrenaline) and one effect of this is significant arteriolar vasoconstriction, which would be expected to reduce nutrient delivery within the microcirculatory systems of muscles and tendons, resulting in poorer healing of microlesions in tendon fibres (which routinely develop and self-heal). Consequently, both muscle fatigue and pain are likely to increase, particularly under conditions of high biomechanical strain when the rate at which such microlesions develop is higher. Second, stress can affect corticosteroid levels (for example, cortisol), which can disrupt mineral balance (via effects on the kidneys) with consequent oedema (this is a central feature of MSD "tunnel syndromes"). Third, one of the consequences of stress affecting the reticular formation is an increased level of muscle activity, which directly increases the biomechanical load within muscles and tendons. Fourth, effects of stress on the immune system include increased production of cytokines, some of which are inflammatory and have been found to play a direct, causal role in the development of some MSD cases (Puduvalli et al, 1996).

In summary, while there is a need for much more evidence to establish a detailed physiological model, researchers have now identified a range of credible mechanisms via which elements of the 'stress response' can directly increase the risk of WMSDs. This knowledge supplements the large and growing body of evidence from workplace studies identifying clear associations between WMSD risk and a wide range of psychosocial hazards as well as and physical ones. Having summarised these hazards, Section 3 of the report reviews information concerning the relative influence of physical versus psychosocial hazards on WMSD risk, and also evaluates the adequacy of current evidence that WMSDs are indeed *work*-related. This section finishes with a summary of risk control strategies related to these different types of hazard, drawing mainly on material from government and industry sources.

Section 4 addresses *Hazard Identification and Risk Assessment Methods*. Again, the large body of available information on these topics and the resources available for this project necessitated a focused rather than fully inclusive approach. Information on assessment methods has been selectively drawn from published research literature and from material prepared by government authorities and in some cases by industry bodies. Finally, Section 5 discusses *Other Barriers to*

Improved WMSD Risk Management, followed by *Conclusions*.

1.3 Extent of the WMSD problem

In economically developed countries such as Australia, musculoskeletal disorders comprise a high proportion of work-related injuries, and are among the most costly in both personal and economic terms (Foley, 1996; National Occupational Health and Safety Commission, 2002; Victorian Workcover Authority, 2004). Australia is no exception to this pattern. According to the Australian National Data Set (the NDS, representing Workers' Compensation data from all Australian jurisdictions), "body stressing" injuries accounted for approximately 41% of compensated, work-related injury and disease cases in Australia in 1999–2000 (Foley, 1996). The mean period of absence from work for such claims was 10.4 weeks (14.5 weeks for injuries to the upper body). In 2004 these figures had changed very little, being 41.7% of injuries, with a mean absence of 9.3 weeks (NOSI, 2004p).

In light of the status of WMSDs as the largest category of occupational disease, a great deal of attention has been directed by Australian governments over the past couple of decades to reducing their incidence – more so than for other types of injury. Up until around 2001, however, there was little evidence of success in decreasing WMSD incidence rates relative to those of other disease categories, commensurate with the preventative efforts of government authorities (Evans & Macdonald, 2001; Paoli & Merllie, 2001), apart from that some specific campaigns that were accompanied by a major change to the system of work, such as the introduction of "no-lift" policies within hospitals. More recently, a National Occupational Health and Safety Commission (2005b) review of work-related musculoskeletal disorders presented figures from the NDS for 2002 and 2003, showing downward trends for three of the four categories of WMSDs since 2001, and overall mean decreases from 1998 to 2003 of from 16% to 29% in incidence rates for the following three categories *Muscular stress while lifting, carrying or putting down*, *Muscular stress while handling objects other than while lifting, carrying or putting down*, and *Muscular stress with no object being handled*. In contrast, the incidence rate for the fourth category – *Repetitive movement, low muscle loading* – increased consistently, by 19% overall over this period.

This last category has the lowest incidence rate, even with its 19% increase. Nevertheless, its upward trend in light of the decreasing trends for injuries attributed to other causal mechanisms is a cause for concern.

1.4 Problems interpreting epidemiological data on causal mechanisms

While the general scope of the WMSD problem is clear, as outlined above, interpretation of epidemiological statistics about such injuries is fraught with problems. Some of these problems are outlined in the 2005 NOHSC Occupational Disease Profiles *Overview Report on Work-Related Musculoskeletal Disorders* (National Occupational Health & Safety Commission, 2005b), with reference to the National Data Set (NDS) for compensation-based statistics (2001-2 and 2002-3) and to data collected by the Australian Institute of Health and Welfare (AIHW).

The NDS nominally differentiates between sudden-onset “sprains and strains” (classifying them as ‘injuries’) and gradual-onset or cumulative MSDs which are coded under “diseases of the musculoskeletal systems and connective tissues”. However, according to the Type of Occurrence Classification System (TOOCS), ‘body stressing’ is the only applicable ‘mechanism of injury’ category for both sudden- and gradual-onset injuries or disorders, which blurs the distinction between acute ‘injuries’ and cumulative ‘disorders’. Body stressing injuries are defined as being caused by:

- muscular stress:
  - while lifting, carrying or putting down objects;
  - while handling objects other than lifting, carrying or putting down objects (pushing, pulling, pressing or throwing objects);
  - with no objects being handled (bending, twisting, reaching, turning, working in cramped positions); and/or from
- repetitive movements with low muscle loading (Foley, 1996).

A problem with the above definition of WMSDs is that it *defines* them in terms of only physical hazards – thus excluding psychosocial hazards from further consideration and hampering a more comprehensive approach to evidence-based risk management.

Also, NDS data about the relative frequencies of specific injury mechanisms is likely to be quite inaccurate because it depends ultimately on the knowledge and insight of those providing the raw data, who in the vast majority of cases have no professional training in either occupational medicine or occupational health and safety. With injuries that are clearly definable and have only a single, clearcut cause, this is not a major issue. For cumulative WMSDs, however, which typically have *multiple* mechanisms of injury, some of which are much more conspicuous and easily identifiable than others, such data are likely to be very substantially biased towards the most obvious, widely recognised factors that involve “muscular stress” during some dynamic form of activity.

There are several reasons for expecting this bias. First, there is a strong association in most people's minds between WMSDs and the performance of physical actions. To some extent this is probably just a consequence of conventional 'western' social constructions of health and illness, in which there is a fairly clear divide between 'physical' and 'mental' health problems (e.g. see Focault, 1973; Hadler, 2001; Jackson, 2005). In this instance, such a viewpoint is further entrenched by the common conceptualisation of WMSDs as 'manual handling injuries' , as is evident in Australian federal and State regulations and codes of practice related to the control of WMSDs; in North America the equivalent term is 'ergonomic injuries'.

A further problem, specific to creation of claims-based data sets such as the NDS, is that questions on incident notification forms (e.g. see www.workcover.gov.au) focus heavily on details about the particular *point in time* when the injury is assumed to have *occurred* and on associated activities and circumstances. This strongly implies that physical injuries such as WMSDs are likely to be due to some physical event or actions, and are most likely to be acute rather than cumulative in onset, which constitutes another reason why gradual-onset WMSDs would tend to be wrongly recorded as sudden-onset injuries along with 'sprains and strains'. In Victoria, changes to the Victorian WorkCover Authority injury coding system in an attempt to distinguish these two types of injury resulted in a large fall in recorded levels of sudden-onset 'sprains and strains', which are now outnumbered by cumulative MSDs (Jackson, 2003). Similar changes are being made in other states, but the effects are not yet evident in the NDS. Recognising the importance of this confusion between these two major subsets of WMSDs, in 2003 the U.K. Health and Safety Executive (HSE) research agenda of their priority program on musculoskeletal disorders identified an important need to develop improved understanding of "the pathomechanisms and epidemiology" of WMSDs and their prevention, including: "studies of the natural history of MSDs *with a particular focus on the development of acute versus cumulative/chronic cases*" (emphasis added).[1]

In summary, there are several distinct problems with information from the NDS about causal factors for WMSDs, stemming both from general community beliefs about the causes of these injuries and from the specific reporting systems from which the data are derived. Consequently, these data are likely to over-estimate the incidence of acute-onset injuries relative to cumulative-onset injuries, and to inflate the role of specific, dynamic actions while under-representing the role of extended exposures to more diffuse, ongoing hazards such as repetitive movements and static loads for which no specific point of injury can be reported. Finally, they entirely conceal the role of psychosocial hazards as opposed to physical hazards.

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[1] HSE June 2003. Aim K-3. http://www.hse.gov.uk/msd/pdfs/researchagenda.pdf

In light of the unreliability of the identification of causal factors within such epidemiological data sets, it is impossible to judge whether the upward trend in NDS incidence rate for injuries attributed to *repetitive movement, low muscle loading* is in fact a genuine increase. It may well be – perhaps associated with increases in work intensification and associated levels of fatigue and stress. Alternatively, the increase might be due to a gradual, ongoing correction to previously very high levels of under-reporting in this category, perhaps due to increasing awareness of the hazardous nature of low force, repetitive movements and static postures. In either case, it seems likely that the documented increase in incidence of the latter type of causal mechanism will continue, and it is therefore important to identify more effective methods for assessing and controlling the hazards associated with work of this kind.

2. METHOD

2.1 Search strategy for identification of studies

In identifying published studies, the following information sources were searched:

1. Electronic library databases:
    - Medline – using OVID search engine
    - OSHROM (Silverplatter Webspirs search engine) includes the following databases and were searched together:
        - HSELine
        - NIOSHTIC
        - CISDOC
        - RILOSH
        - OEM (Medline subset)

2. National and international research and regulatory authorities:
    - National Occupational Health and Safety Commission of Australia
    - Occupational Health & Safety regulatory authority in each state of Australia
    - National Institute of Occupational Safety and Health
    - Health and Safety Executive
    - Regulatory and Guidance documents from Australia (including most states); UK, Spain, Sweden, Netherlands, France, Belgium and several US states.

2.2 Strategies and search terms

Searching of Medline (using the Ovid search engine):

Several search strategies were used:

1. MESH terms *cumulative trauma disorders* and *exp risk* and words *musculoskeletal disorders* in the title or abstract
2. MESH terms (*muscle fatigue* or *fatigue* or *mental fatigue*) and *exp risk*
3. MESH terms *cumulative trauma disorders* and *occupational exposure*

Searches were limited to publications in English and published between 2000 and 2006.

Searching of OSH-ROM (using the WebSpirs search engine):

Several search strategies were used, including (but not confined to):

1. *musculoskeletal disorders* and (*risk assessment* or *risk evaluation*)
2. (*posture* or *musculoskeletal disorders*) and (*assess** or *method**)
3. (*musculoskeletal disorders*) and (*occupational or work-related*) and (*risk or hazard*) and *evaluation*

Searches were limited to publications in English and published between 2000 and 2006.

These references were supplemented with a considerable number of relevant references that were already in the possession of the authors

2.3 Review of search results

The titles and abstracts of the records retrieved with these strategies were assessed for relevance to this review (see Section 5.1 below, Identifying Studies).

Inclusion and Exclusion criteria

A research study was considered for inclusion in this review on the following basis:

- It was an empirical quantitative study, review article or meta-analysis
- It focussed on the causes of musculoskeletal disorders, the measurement of risk factors for musculoskeletal disorders, interventions to reduce musculoskeletal disorders, and barriers to the implementation of such interventions.

Studies were included in the review if they fitted the following criteria:

- Both laboratory and field studies were used
- Narrative reviews, systematic reviews and meta-analysis were used
- English only – as translation in the study timeframe was difficult
- Government regulatory and guidance documents were included
- Standards were included

Identifying studies

A research assistant screened the titles and abstracts of retrieved records to identify all possible inclusions. In the case of review articles, a manual search of the citations was conducted to identify any additional studies that might warrant inclusion. One or both of the senior investigators then double-checked these records against the inclusion and exclusion criteria, and later assessed the full reports in more detail to confirm their relevance or otherwise.

In addition, a large number of existing documents already held by the senior investigators were similarly reviewed for possible inclusion, and relevant documents identified.

Abstraction of data

Information was abstracted by a single reviewer, who entered it directly into a database that now comprises Appendix A (see below). In the case of documents containing information that was relevant to formulation of a set of hazard assessment methods for use Stage Two of this project, information was also entered into a second database, which is presented as Table 2.

3. EVIDENCE IDENTIFYING MAIN HAZARDS

As noted in Section 1, the following summary of current knowledge of the main hazards or causal factors for WMSDs is based primarily on several recent reviews of literature that together provide comprehensive coverage of all major areas of this domain. Information from these reviews has been supplemented by reports on more specific topics where these were considered to add something substantive.

The main review documents used were:

- *Musculoskeletal disorders (MSDs) and workplace factors* (Bernard, 1997)
- *Musculoskeletal disorders and the workplace: low back and upper extremities* (National Research Council and Institute of Medicine, 2001)
- *Low back disorders: evidence-based prevention and rehabilitation* (McGill, 2002)
- Special issue of *American Journal of Industrial Medicine* on 'Biobehavioral mechanisms of work-related upper extremity disorders'**,** May, 2002
- *The impact of job demands and workload on stress and fatigue* (Macdonald, 2003)
- *Review of National Standard and Codes for Manual Handling – Issues papers 1, 2 and 6* (National Occupational Health and Safety Commission, 2003a, 2003b, 2003c)
- *Work-related musculoskeletal disorders: the epidemiological evidence and the debate* (Punnett and Wegman, 2004)
- *Ergonomics Approaches to the Prevention of Work-Related Musculoskeletal Disorders. An Analysis and Critical Review of Existing National, and Regional Standards and Guidelines*. A report prepared on behalf of the International Ergonomics Association for the International Labour Organisation. (Macdonald et al, 2004)
- *Workload, stress and psychosocial factors as hazards for musculoskeletal disorders* (Macdonald, 2004)
- *Risk factors for occupational overuse syndrome (OOS): literature review* (Simmonds et al, 2005).

Amongst the recent reports on more specific topics, the following were found to be of particular value:

- *Risk factors in the onset of neck/shoulder pain in a prospective study of workers in industrial and service companies* (Andersen et al, 2003)
- *Stressful Psychosocial Work Environment Increases Risk for Back Pain Among Retail Material Handlers* (Johnston et al, 2003)

- *The role of work stress and psychological factors in the development of musculoskeletal disorders: The stress and MSD study* (Devereux et al, 2004)
- *Job strain, iso-strain, and the incidence of low back and neck injuries. A 7.5-year prospective study of San Francisco transit operators* (Rugulies and Krause, 2005).

The balance of evidence from these various documents provides a substantially different view of the main causal factors for WMSDs than that which was current during the 1980s and early 1990s, when much of the groundwork for Australia's current manual handling regulations and codes of practice was undertaken. During that era, available evidence was largely confined to physical hazards of various kinds with a strong emphasis on those associated with 'heavy' work, although risks associated with repetitive work and static postures were increasingly being acknowledged. (Department of Labour, Victoria, 1988; Evans and Macdonald, 2001). During the 1990s, coverage of these latter hazards was incorporated into the *National Code of Practice for the Prevention of Occupational Overuse Syndrome* and later documents (National Occupational Health and Safety Commission, 1992), Occupational Health & Safety Authority, Victoria, 1992), Worksafe Victoria, 2000b), and all such Australian documents now include reference to work organisation and job design as hazards that need to be controlled. However, the *extent* of coverage and level of detail concerning work organisation, job design and psychosocial hazards in WMSD risk management guidance material is still much more limited than the coverage of physical hazards (Bernard, 1997; Bongers et al., 1993; Devereux and Buckle, 2000a, 2000b; Hoogendoorn et al., 2000; Myers et al., 1999; National Research Council and Institute of Medicine, 2001; National Occupational Health and Safety Commission, 2003c). Gaps between knowledge and workplace practice are discussed at greater length in Sections 4 and 5 below.

3.1 Overview of evidence

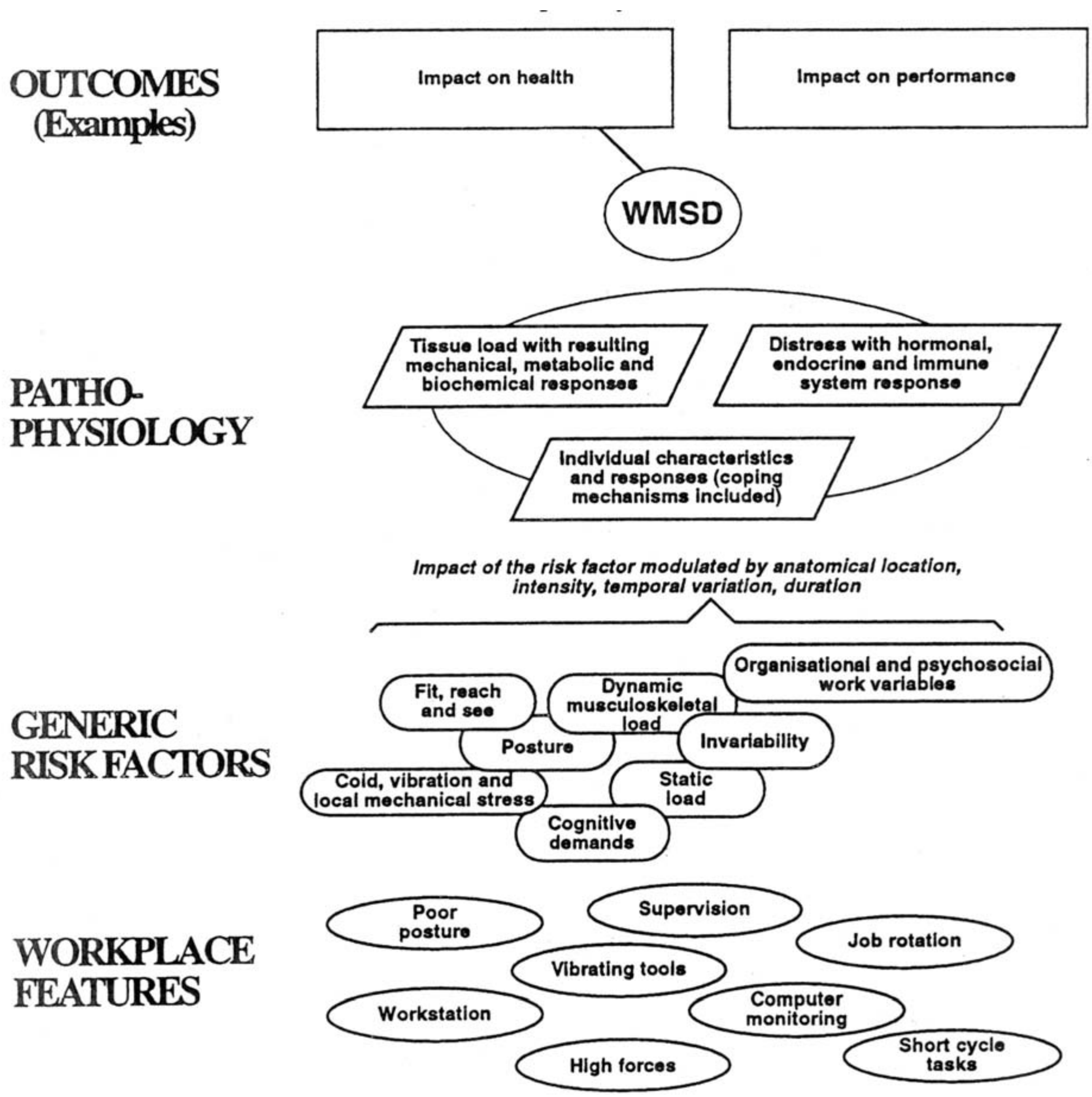
The current state of evidence concerning causes of WMSDs, identifying the specific types of workplace hazards that need to be controlled, is summarised here in the form of three conceptual models, depicted in Figures 4, 5 and 6. Each of these is well founded on empirical evidence, and they have many elements in common, but each highlights somewhat different aspects of the complex functional relationships and pathways via which different types of hazard influence the risk of WMSDs. Figure 4 is taken from Kuorinka and Forcier (1995, p.9); Figure 5 is the conceptual framework presented in the 2001 report of the US National Research Council and Institute of Medicine Panel on Musculoskeletal Disorders and the Workplace (National Research Council and Institute of Medicine, 2001); and Figure 6 shows a composite model developed for the present project, adapted from Macdonald (2004; 2006a).

In the present context, key points of interest in the Kuorinka and Forcier model (Figure 4) are the following:

- Hazards (i.e. factors in the bottom two layers of the figure) are subdivided to separate (although imperfectly) particular 'concrete' features of workplaces and jobs, such as vibrating tools and short cycle tasks, from more abstract constructs which they term 'generic risk factors' such as static load and cognitive demands

- The 'pathophysiological' processes identified in the third layer are subdivided into those resulting from external biomechanical loads and those associated with "distress", i.e. with physiological components of the stress response.

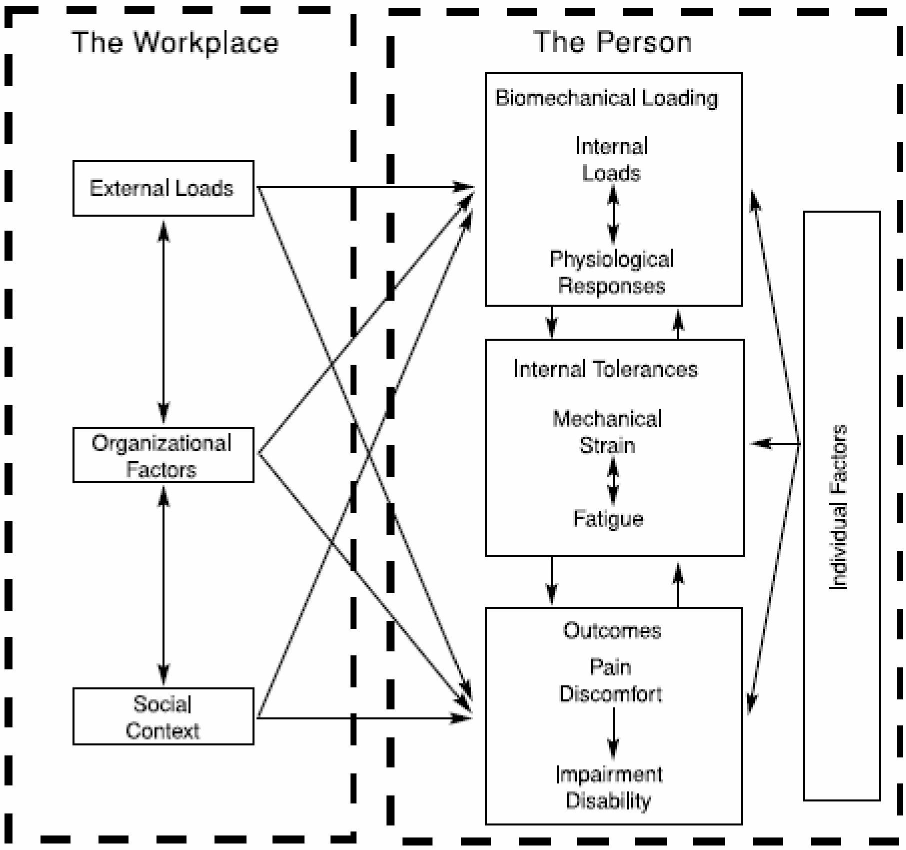
Figure 4. A model of hazards and risk factors that may cause WMSDs (from Kuorinka and Forcier, 1995)



The model shown in Figure 5 represents very much the same set of information as that in Figure 4, but this framework is different in that:

- its two main subdivisions are between workplace factors and personal factors
- workplace factors are subdivided into those related to external loads, to organizational factors, and to social context; these categories cut across the two bottom layers of Kuorinka and Forcier's model (Figure 4)
- personal factors (which correspond most closely to 'pathophysiology' in Figure 4) are here subdivided into personal outcomes (discomfort, pain, etc), along with two categories representing the internal effects of workplace factors.

Figure 5. The model of hazards and risk factors for WMSDs that was developed by the US National Research Council, 2001 (National Research Council and Institute of Medicine, 2001).



Interestingly, although the latter model includes 'physiological responses' to workplace factors among the internal states depicted, it does not refer specifically to 'stress', despite the large body of evidence on this topic available to the authors. In contrast, the earlier Kuorinka and Forcier model (Figure 4) included "Distress with hormonal, endocrine and immune system response". It is probably significant that the earlier model originated in Europe, whereas the 2001 model was developed in the USA within the highly politicised context surrounding introduction (and subsequent removal) of the OSHA legislation known as the "ergonomics rule" (OSHAb).

3.1.1 The present conceptual model

The third model, shown in Figure 6, is a composite one adapted from Macdonald (2004, 2006a) that has been developed for the present project. It is based on: evidence from previous reviews linking a wide range of work and job factors with WMSDs (including the evidence represented in Figures 4 and 5 above); ergonomics literature concerning the nature of task demands, workload and fatigue and their effects on performance and health; and reviews of workplace stress and its causal linkages with MSDs) (Bernard, 1997; Bongers et al., 1993; Devereux and Buckle, 2000a; 2000b; Evans and Patterson, 2000; Hoogendoorn et al., 2000; Moray, 1988; Macdonald, 2000; Myers et al., 1999; Nachreiner, 1995; National Research Council and Institute of Medicine, 2001; National Occupational Health and Safety Commission 2003c; Rick et al., 2001; Sauter et al., 1997; Siegrist, 1996; Tsang and Wilson, 1997).

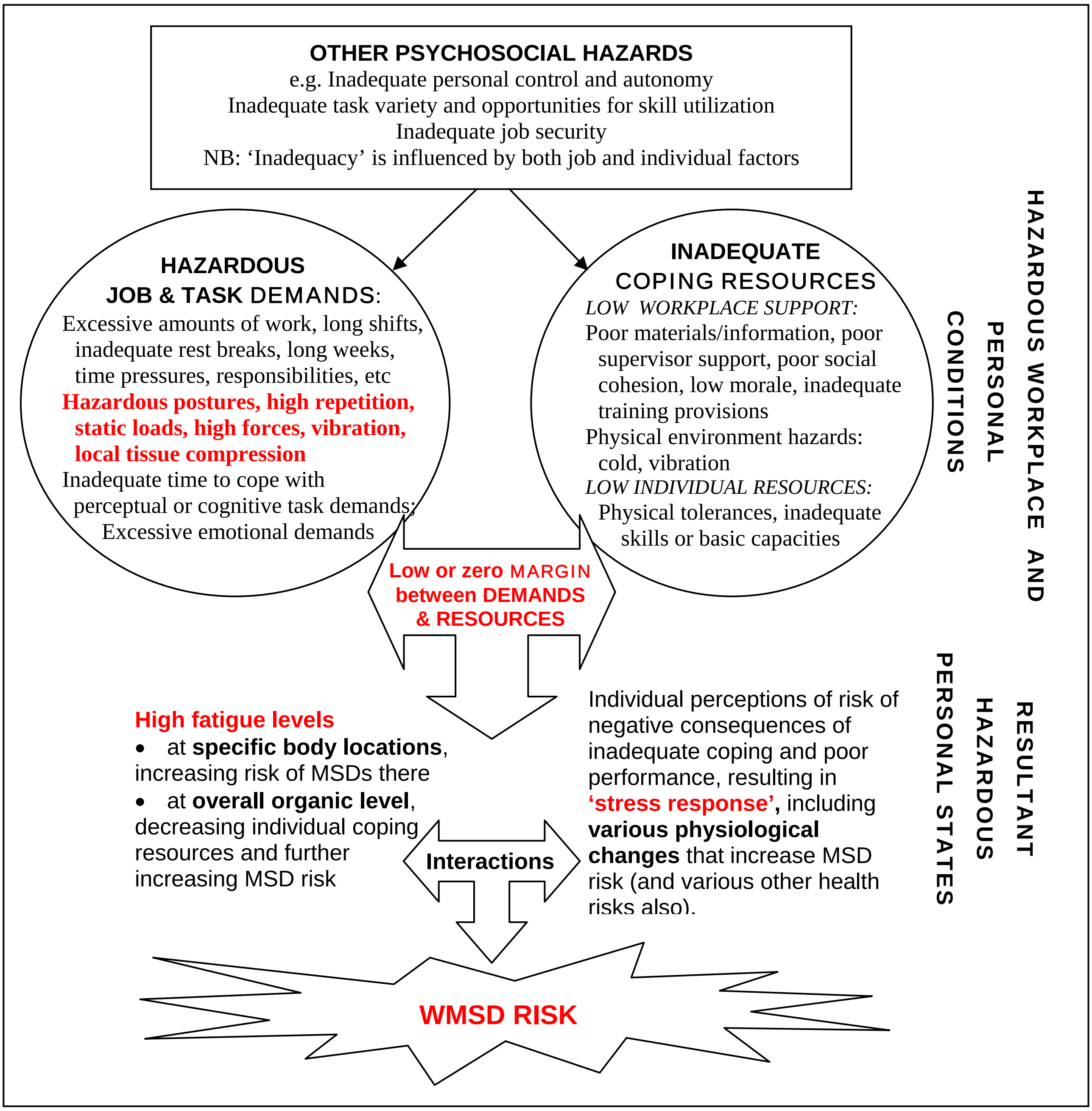
Centrally important in this model is the size of the margin between demands and resources[2]: when this margin is small or non-existent, workers will experience high levels of ***fatigue*** (assuming that they are *trying* to maintain performance). It should be noted that effort expenditure tends to deplete some personal resources, which may result in performance degradation due to fatigue unless there is sufficient rest to enable replenishment of the required resources. Fatigue in this sense is not *necessarily* reflected in a subjective experience of tiredness (Job & Dalziel, 2001). In addition, when there is a significant perceived risk of suffering negative consequences due to inadequate coping, high ***stress*** levels become more likely, with possible behavioural, psychological and physiological consequences as outlined below. Consequently, both muscle fatigue and stress are conceived here as important mediators of the effects of workplace hazards on WMSD risk (Bongers et al., 1993; Devereux et al, 2004).

As shown in Figure 6, the workplace and personal conditions that can influence stress, fatigue and WMSDs can be divided into three categories: the ***demands*** (both physical and psychological) with which workers have to cope in order to perform their jobs; the ***resources*** (both workplace and

[2] 'resources' refers here to both personal resources (i.e. personal capacities, competencies, energy and motivation) and workplace and organisational resources (e.g. adequate equipment, staffing level, available information, supportive management and co-workers, etc)

personal factors) that are available to support workers' coping; and ***additional psychosocial factors*** that do not fall within either the Demands or Resources categories. Thus, WMSD risk arises from the combined effects of these factors, with the contributions of individual factors expected to vary considerably between different situations according to the specific combinations and levels of factors present. It is therefore unreasonable to expect that all individual research studies should identify the same set of factors as being most important (even assuming that the same measures of the same factors were universally applied, which of course is not so). Similarly, it is unreasonable to expect that a particular set of control strategies can be prescribed for universal application to achieve WMSD risk control across all, or even most, workplaces.

Figure 6. A composite, ergonomics model of work-related hazards for musculoskeletal disorders



Hazardous levels of *Job and Task Demands* are among the most frequently cited causes of both occupational stress and associated illness or injuries such as MSDs (Andries et al., 1996; Bernard, 1997; Bongers et al., 1993; Cox and Griffiths, 1996; Cox et al, 2000; Devereux and Buckle, 2000a, 2000b; Karasek et al., 1998; National Research Council and Institute of Medicine, 2001; Paoli and Merllie, 2001; Randall et al., 2002; Rick et al., 2002; Wooden, 2001). For example, Bongers et al (1993) concluded from their reviews of research evidence that "monotonous work, high perceived workload, and time pressure are related to musculoskeletal symptoms". Total hours worked also falls within this general category; this factor is particularly important because it determines each individual's level of cumulative exposure to all other workplace hazards, and even in workplaces where specific hazards are well controlled, very long hours create higher fatigue levels and reduce the opportunity for recovery between work shifts. The total amount of work to be completed is another important factor in this category; having to complete large amounts of work creates 'work intensification' – particularly if there are associated deadlines and time pressures – with an associated reduced duration of informal breaks and less opportunity for recovery from fatigue during the course of a work shift. In circumstances where people perceive themselves as having a lot of responsibility (in terms of possible major consequences of performance errors), or when they just feel that it is important to perform very well (e.g. because of job insecurity), they are more likely to adopt performance strategies requiring higher effort expenditure (e.g. being especially careful to perform all actions with maximum precision, or in the minimum possible time), which increases the risk of excessive levels of fatigue, and possibly of high stress levels also.

Moving from overall job demands to *task-specific* demands, these can be subdivided in various ways; in Figure 6 they are categorized simply into physical and mental subgroups, although each of these can be sub-categorised. The main subtypes of physical task demand (at least in the context of WMSD risk management) are: forceful exertions (whole body exertions involving the use of large muscles, and localised exertions including, for example, pinch and palmar grips); sustained, low-level muscle exertion (static loads), particularly in non-neutral or awkward postures; highly repetitive movements; vibration interacting with muscular exertion; local tissue compression; mechanical pressure on body tissue; and very cold environments. It is these physical aspects of task performance demands that have been most widely recognised as WMSD hazards, and there is a large body of evidence demonstrating the various biomechanical and physiological mechanisms via which they increase WMSD risk (e.g. see Bernard, 1997; National Research Council and Institute of Medicine, 2001).

Mental task demands include both perceptual/cognitive and affective or emotional aspects. In the first sub-category are requirements for perceiving (carefully looking, listening, touching, etc, to obtain and interpret information); decision-making and remembering (categorising, deciding, problem-solving); and psychomotor control (executing accurate, precise, well-timed motor actions). Also in this sub-category is the more general demand for attentional effort and ‘executive’ control (concentrating, sharing attention optimally, avoiding distraction). In the second sub-category are affective or emotional demands, such as for the control needed to display the “correct” façade as required for satisfactory job performance, and to hide real feelings when necessary.

Because of the strong relationship between level of information processing requirements and required performance time (in accordance with Hick’s Law and/or Fitts’ Law; see Proctor & Van Zandt, 1994), high levels of perceptual/cognitive demands increase the risk of workers experiencing excessive time pressures, which can increase the risk of errors and associated injuries. Also, coping with high levels of all types of mental task demands tends to be fatiguing, as in the case of physical demands, and the resultant depletion of cognitive or emotional coping resources may increase the risk of excessive or chronic stress levels. By these various means, mental task demands can increase the risk of WMSDs (Gaillard, 2001; Hoffmann et al., 1993; Job and Dalziel, 2001; Macdonald et al., 1999; Proctor and Van Zandt, 1994).[3]

Levels of job and task demands need to be balanced against people’s coping resources, since an inadequate margin between the two is hazardous, as shown in Figure 6. In this model, factors within the ‘coping resources’ category are subdivided into those stemming from levels of workplace support, and those stemming from the individual’s own coping resources. It has been found in many studies that jobs with very high demands and low support have a higher risk of stress-related illnesses and disorders, which includes WMSDs (Greller, Parsons & Mitchell, 1992; Johnson & Hall, 1988; Karasek et al., 1998; Theorell, 1998).

Some forms of workplace support are *instrumental* in nature; such support directly facilitates work performance by means such as the provision of timely and useful information or of well functioning equipment, which effectively reduce the amount of effort that has to be expended and thereby reduce the rate at which individual resources diminish during performance. Increased *social, interpersonal* or *affective* support can also increase an individual’s coping resources, for example by increasing their morale and general arousal level, with consequent increase in their level of

[3] It should be noted that, just as coping with appropriate levels of physical demands can increase health and physical fitness, so coping with appropriate levels of mental demands can increase job satisfaction and general wellbeing. In both cases, the key requirement is to achieve an optimal balance between demands and coping resources.

available attentional resources as described by Kahneman's model (Kahneman, 1973). Conversely, a workplace environment in which there are high levels of interpersonal conflict will tend to reduce the resources people have available to cope with their work demands. Provision of performance feedback can function both as affective or interpersonal support, and as instrumental support in that it conveys information that can be used to "fine tune" performance strategies which might result in reduced effort expenditure and hence a reduction in fatigue, with consequent (relative) improvement in coping resources. Thus, increased workplace support – whether instrumental or social – can increase coping resources and thereby reduce the risk of WMSDs as shown in Figure 6.

Another set of workplace variables that affect coping resources are those described in Figure 6 as 'physical environment hazards'. Those most directly relevant to WMSD risk are *cold*, which has been demonstrated in many studies to increase this risk, and *vibration.* Vibration here refers to environmental sources of whole-body vibration such as from a vehicle. Vibration stemming from use of a power tool (hand-arm vibration) is categorised separately as a *demand*, since it is inherent in task performance, rather than as an environmental factor; however, this separation might be seen as somewhat artificial and it is not an important one in the present context. Environmental cold and vibration are placed here in the model because they both reduce people's physical 'coping resources' in ways that increase their WMSD risk.

Considering each individual's basic levels of *personal* coping resources, these are determined to a significant degree by inherent physical and psychological capacities, limitations and general behavioural tendencies. In addition, levels of general education and more specific training, past experience in the job, levels of fatiguing demands and stressors experienced outside the workplace, age and possibly gender and cultural variables might have a significant influence. The relevance of each individual factor can only be determined in relation to the nature and levels of the work and job demands with which that person is required to cope. Most importantly in the present context, the resources that each individual brings to their job can be significantly boosted or depleted by the degree of workplace support that is available, including the provision of appropriate training, and by the nature of the social and physical environment as outlined above (also see Macdonald, 2003).

In Figure 6 there is a third category of work-related hazards, termed *other psychosocial hazards*, that can affect levels of both *demands* and *coping resources*. This third category contains all non-physical factors that can affect WMSD risk and do *not* fall within the demands or coping resources categories. They are termed 'other' psychosocial hazards because within the usual risk management framework, 'hazards' are generally subdivided simply into physical and 'psychosocial' categories, which means that most of the factors included here as demands or coping resources would be listed by others within a single, very large category of ‘psychosocial hazards’ (e.g. Cox and Griffiths, 1996). The present model is more highly differentiated, following the more usual pattern in organisational psychology and occupational health psychology (e.g. Karasek et al, 1998).

Typical examples of ‘other psychosocial hazards’ include: unpleasant shift schedules (inflexible, unpredictable, unsocial, night work); lack of control over work (low autonomy, low opportunities for participation); lack of variety/interest (short work cycles, fragmented or meaningless work, under-use of skills, monotony); role conflicts/ambiguities; home/work conflicts; and job insecurity and career uncertainty. Another factor that might be included in this category is a high rate of workplace change; this requires frequent learning and re-learning of new information and procedures which effectively reduces people’s coping capacities since they are performing at lower levels of expertise for more of the time. Consequently, higher levels of effort are required, and there is a greater potential for fatigue and/or stress to become problematic.

3.1.2 Linkages between psychosocial and physical hazards

It is now undisputed (at least by occupational health psychologists and medical scientists) that when someone experiences a stress response, the effects are not ‘all in the mind’. As discussed in Section 1.2, the stress response is multidimensional, comprising measurable changes in human cognitive and performance characteristics and in physiological functioning, as well as in how we feel (e.g. see Ader et al, 2001). Some of the changes within the central and autonomic nervous systems, the endocrine system and the immune system mechanisms constitute pathways via which a stress response can increase the risk of WMSDs (see Figure 3). On such grounds, Pransky et al (2002) concluded that “Current knowledge on this issue indicates a web of causation [of WMSDs], which is multifactorial and dynamic ...” and that: “There is ample evidence for the role of workplace stress in the causation and exacerbation of these disorders” (p.443). More specifically, they pointed out that:

> “... a worker’s response to job demands (either physical or psychosocial), or workstyle [Feurstein et al., 1999b], may trigger certain physiological responses that intensify pathological processes in the LB [low back] or UE [upper extremities] regions. Examples of such physiological processes include sustained motor unit activity [Lundberg et al., 1999] and/or elevations in norepinephrine, epinephrine, adrenocorticotropin hormone, and cortisol [Frankenhaeuser and Lundberg, 1982; Gerra et al., 2001].” (p.444).

Consistent with the above, it has been demonstrated that “mental” demands and “high precision” demands can induce static muscular activation patterns, at least in the trapezius muscle (e.g. Westgaard et al 1993; Waersted et al, 1996). More recently, Marras and colleagues (2002) provided a laboratory demonstration of how a *psychosocial* hazard can increase the risk of MSD injury in a lifting task. Subjects in this study performed a lifting task, with and without the presence of a psychosocial hazard in the form of visual feedback indicating that their performance was inadequate. Results showed significant increases in people's spinal loadings and in various muscular and kinetic responses when the psychosocial hazard was present, compared with when it was not.

A different form of evidence is available from various epidemiological studies – for example, a recent large-scale prospective study of the role of psychosocial hazards in the development of back pain among 6311 retail material handlers (receivers/unloaders, stockers, managers) in 160 different stores of a large US chain (Johnston et al, 2003). Data on physical and psychosocial hazard levels, along with demographic and personal factors including back pain, were collected at baseline, then six months later. Based on data analyses that controlled for the effects of physical hazards, particularly lifting activities, as well as various potential confounding factors (e.g. age, gender, pre-existing back pain), they found significant effects of a range of psychosocial hazards, of the kinds depicted in Figure 6, on the incidence of increases in back pain over the six-month period. They pointed to various plausible mechanisms that could explain their results, including the observation that people are likely to perform their work somewhat differently when they are stressed. For example, they may respond to perceived time pressures or high workload levels by performing more hurried (faster and possibly jerkier) actions, and/or by exerting higher forces than otherwise. In these kinds of ways, behavioural changes in response to psychosocial hazards can directly increase the physically hazardous nature of work activities. Further, such performance changes might, in some jobs or situations, also increase the probability of performance errors and resultant accident risk.

3.1.3 Issues in evaluating the evidence

Based on a review of evidence up to around 2000, the USA National Research Council and Institute of Medicine (2001), concluded that:

> "The weight of the evidence justifies the identification of certain work-related risk factors for the occurrence of musculoskeletal disorders of the low back and upper extremities" (p. 364);
> "Modification of [those] physical and psychosocial factors could reduce substantially the risk of symptoms for low back and upper extremity disorders" (p. 365); and
> "The weight of the evidence justifies the introduction of appropriate and selected

> interventions. . .to reduce physical as well as psychosocial stressors. . .[through] the development of integrated programs that address equipment design, work procedures, and organizational characteristics" (p.*365).*

However, past critics have pointed to the need for improved data collection and analysis methods and research designs. In particular, they have highlighted the need for a greater number of prospective, longitudinal studies rather than cross-sectional or retrospective ones. In accord with this recognised need, recently published studies include several large, longitudinal ones (Andersen et al, 2003; Johnston et al, 2003; Cole et al, 2005; Devereux et al, 2004; Rugulies and Krause, 2005), the results of which have been entirely consistent with the balance of evidence from past cross-sectional studies. It is now clear, therefore, that cross-sectional study designs have not been a significant source of misleading conclusions. Discussing this issue, Punnett and Wegman (2004) commented that:

> "It is important to note that, in general, the available longitudinal evidence has confirmed the conclusions previously drawn from cross-sectional studies regarding the associations between working conditions and MSDs." (p.17)

The recent longitudinal studies cited in the above paragraph had prospective rather than retrospective designs, but even in the case of *retrospective* longitudinal studies, which typically suffer from the memory limitations of respondents, there is evidence that this is not necessarily a substantive problem. For example, Koster and colleagues (1999) reported results from a study in which they compared 1993-94 responses to a set of questions about remembered MSD symptoms and exposures to physical and psychosocial work-related hazards approximately 25 years ago (1969-70), and compared these responses with their much earlier ones in 1969-70. As expected, they found many discrepancies between the two sets of responses; importantly, however, the effects of these discrepancies on calculated relative risks were minimal.

In recent years the need to address such issues has been recognised, and many of the more recently published studies are remarkable for the lengths to which the researchers have gone to ensure the validity and reliability of their methods and conclusions. For example, Devereux et al (2004) verified the validity of their respondents' questionnaire responses concerning levels of work-related physical and psychosocial hazards by conducting several additional ancillary studies with sub-samples of their respondents, in which more detailed information was obtained by various means, including video-recording of physical hazards in their workplaces and semi-structured interviews by researchers who were 'blind' to other information.

Apart from technically-based criticisms concerning research study design, there is still resistance in some quarters – particularly in the USA – to accepting the above conclusions. The relative importance of *work-related* hazards as opposed to *non-work* hazards or risk factors has been questioned, and the validity of attributing physical injuries such as WMSDs to *psychosocial* hazards as opposed to physical ones is still held by some to be inadequately substantiated. Each of these questions is addressed below.

Work-relatedness of WMSDs

In the USA, there has been considerable controversy, mainly at a political level, over the work-relatedness and relative importance of even *physical* WMSD hazards, as opposed to non-occupational hazards. In reviewing some of these issues, Punnett and Wegman (2004) pointed out that it is unreasonable to conclude that causal linkages between particular physical hazards and WMSD risk are weak or non-existent, simply because of the wide variation in the magnitude of published statistical associations between these factors. They wrote that:

> As with most chronic diseases, MSDs have multiple risk factors, both occupational and non-occupational. In addition to work demands, other aspects of daily life, such as sports and housework, may present physical stresses to the musculoskeletal tissues. [Risk varies with a wide range of factors including] ... systemic diseases such as rheumatoid arthritis, gout, lupus, and diabetes. ... age, gender, socioeconomic status, and ethnicity. ... obesity, smoking, muscle strength and other aspects of work capacity. ... the etiology of these disorders in the population as a whole is multifactorial. .... Not everyone with MSDs has ergonomic exposures at work, and not everyone exposed at work develops a MSD. Because these disorders are so common in the general population, and because of the many non-occupational risk factors, some have argued that occupational factors cannot account for a large proportion of the musculoskeletal disease burden in general. This is a non sequitur. The presence of one risk factor does not negate another. ... In fact, [it has been] estimated that about 40% of all upper extremity MSDs in the total US employed population were attributable to occupational exposures. (Punnett and Wegman, 2004, pp.13-14)

To give some rough idea of the magnitude of such associations, the authors of the 2001 US National Research Council calculated ‘attributable fractions’ (AFs) for the most commonly reported hazards. The AF is intended to indicate the proportion by which WMSDs would be reduced in the population of workers exposed to that hazard, if the hazard were eliminated. However, these values were so wide-ranging (e.g., with back disorders, AF values for frequent bending and twisting ranged from 19% to 57%, and from 18% to 80% for whole-body vibration), as to be of little practical value – particularly since it is not possible to judge the extent to which such variation represents differences in the design and methods of different research studies, as opposed to genuine differences between different situations in the actual effects of these hazards.

There are many potential causes of the variation in observed degree of association between levels of MSD risk and observed hazard exposures. A centrally important issue is variation in how hazard 'exposure' levels are defined and measured, which is partly because 'exposure' is a somewhat vague concept. The term is sometimes used to refer simply to *which* hazards people are exposed to, while at other times it is used to mean the *extent* of exposure; and 'extent' of exposure often refers just to the *severity* of the hazard as assessed at a particular point in time, while sometimes it refers also (or instead) to the *duration* of exposure to the hazard. For cumulative WMSDs, hazard exposure durations are very important, in addition to hazard severity at a given point in time, but accurate and reliable reports of exposure durations are very difficult to obtain.

When both hazard severity and hazard duration are known, the total 'dose' of the hazard to which people are exposed can be calculated, but in the case of WMSDs, this is not very helpful because the association between 'dose' and risk is poorly understood. Given the existence of multiple, interacting hazards that are measured in variable and often unreliable ways, this is not a surprising situation. Also, the way in which WMSD 'cases' are defined is very variable, ranging from measures of symptom severity through to medically diagnosed conditions; and even in the case of medical diagnoses, there is wide variation in diagnostic practices (Sluiter et al, 2000; National Research Council and Institute of Medicine, 2001). Further, for some hazards the relationship between risk and exposure level would not be expected to be linear; for example, *intermediate* levels of 'workload', 'autonomy', and level of physical energy expenditure might in some situations have a lower risk than either very low levels or very high ones, and it is for this kind of reason that researchers in more recent studies sometimes categorise exposure levels into tertiles (e.g. Rugulies and Krause, 2005)

Punnett and Wegman (2004) pointed out that variation in how exposure levels are transformed statistically (e.g. dichotomised around the median; divided into tertiles; or treated as continuous variables) is another factor contributing to the observed variation in strength of association between levels of MSD risk and hazards. Other such factors include:

- variation in the range of hazard exposure levels within different data sets, which can be expected to vary substantially between job types and industry sectors as well as possibly *within* these categories, and
- correlations between different hazards and risk factors that are not (or cannot be) completely controlled statistically.

These latter variables are likely to be particularly problematic when considering the relative influence of physical versus psychosocial hazards, as discussed in the section below. To minimise these problems, "... investigators must select populations carefully to obtain sufficient range in multiple covariates, and sufficiently uncorrelated distributions, even while gaining access to working populations is becoming increasingly difficult." (Punnett and Wegman, 2004. p.17)

Despite methodological problems such as those outlined above, scientists familiar with the large body of evidence on WMSD causal factors are virtually unanimous that existing evidence unequivocally demonstrates strong, causal linkages between work-related physical hazards and WMSD risk.

Relative influence of physical versus psychosocial hazards on WMSD risk

For many reasons, it is often difficult to interpret the relative strength of statistical associations between WMSD risk and each of these two hazard categories. One common problem is that the two types of hazards can be correlated with each other, typically because some types of work organization or job design tend to generate particular sets of physical and psychosocial hazards. For example, manufacturing work that is organised in a conventional 'assembly line' fashion tends to entail physically repetitive actions and/or static postures, which are physical hazards, and workers performing this kind of job tend to have relatively low levels of 'control' and perhaps also to experience high time pressure related to high production targets, both of which are psychosocial hazards. In these circumstances, it can be difficult or impossible to disentangle the relative effects of physical and psychosocial hazards on WMSD risk.

Another problem that can stem from a particular kind of work organisation or job design is systematic restriction of the ranges of some types of hazard more than of others, such that hazards with greater variance are more able to demonstrate associations with WMSD risk. Thus, a sample of workers might be performing a variety of different jobs which are similar in terms of their physical hazards but, being in different workplaces with varying supervisory practices and management styles, vary considerably in levels of psychosocial hazards such as time pressures, overall workload, supervisor support, and so on. This kind of pattern was demonstrated in an Australian study involving workers performing low-skilled, repetitive manufacturing tasks; standard ergonomics measures were used to assess physical hazards related to force exertions and adverse postures, but these varied very little and showed little relationship with the outcome measures of fatigue and stress – although cycle time was a significant predictor. However, mental workload, which is a and some other psychosocial hazards together accounted for substantial proportions of variance in these outcomes (Macdonald et al, 2000). Similarly, Evans & Patterson (2000), in a study of neck pain among keyboard users, found that neck and shoulder pain was *not* significantly related to the 'ergonomics' quality of their workstations but *was* significantly related to their stress levels; in this study also, the degree of variation in workstation quality was very limited.

Difficulties in interpreting the relative strength of associations between WMSD risk and physical versus psychosocial hazards also arise from the general lack of agreement – and sometimes downright confusion – concerning the conceptual nature of 'psychosocial' hazards. This has resulted in an extraordinarily varied range of measurement methods and many inconsistencies between studies.

In its most general sense, 'psychosocial' can be taken in this context to mean simply 'non-physical'. However, this very broad meaning encompasses such a varied range of factors that it is not very meaningful or practically useful. In the conceptual framework adopted for the present project, shown in Figure 6, non-physical hazards fall within several different categories, relating to excessive task or job demands, inadequate coping resources (subdivided into workplace and personal factors), and other aspects of the job or workplace. And in addition to the fairly stable personal factors such as age, gender, skills and personality that are categorised here as 'personal conditions', there are other personal variables of a more transient kind such as fatigue and 'stress' which are strongly influenced by workplace factors; these are termed 'hazardous personal states'.

Macdonald (2003; 2006a, 2006b) has argued that these various distinctions between different subcategories of 'psychosocial hazards' are important because of their implications both for practical risk management strategies, and for decisions concerning data measurement and analysis in studies such as those under discussion here. However, few epidemiological researchers make any such distinctions between different types of psychosocial hazard, and many include measures of workplace psychosocial hazards in the same category as measures of workers' responses to these and other hazards. The latter category (workers' responses) includes both *direct* scale measures of stress, fatigue, job satisfaction, and so on, and indirect indicators such as the 'job strain' or 'iso-strain' indices, which are calculated from ratios of different categories of *workplace* psychosocial hazards (Johnston and Hall, 1988; Karasek et al, 1998).

In contrast to most other researchers, Devereux and colleagues (2004) present a much more highly differentiated view of WMSD hazards and risk factors. They distinguish physical and psychosocial 'work factors' from demographics, organisation factors, individual trait, attitude and well-being factors, and 'stress reactions' (comprising measures of perceived job stress, perceived life stress, depression, mental strain, and psychosomatic symptoms). These distinctions parallel many of those depicted in Figure 6. Using this framework to structure their data analyses, they found that 'perceived job stress' was involved as an intermediate factor between high exposure to physical and psychosocial work risk factors and WMSD symptoms relating to the low-back, the upper back and hands/wrists, and that stress reactions (measured here as depression and psychosomatic symptoms) acted independently to increase the likelihood of developing self-reported musculoskeletal complaints. Like many others, they also found that exposure to high levels of *both* physical and psychosocial work risk factors resulted in the greatest likelihood of reporting musculoskeletal complaints.

Finally in this section it is interesting – despite the many problems and provisos that must be borne in mind when interpreting them – to look at some recent examples of quantitative indicators of the relative influence of physical versus psychosocial hazards on WMSD risk, in the form of either odds ratios (OR) or correlations.

Andersen et al (2003) reported results from a four-year prospective cohort study (baseline plus three annual data collections) using self-reported data from a final sample of 1546 workers in industrial and service companies in Denmark. Results from their final regression models are shown here separately for 'symptom' cases (self-reported onset of neck/shoulder pain) and 'clinical cases (medically reviewed cases with pressure sensitivity):

	Odds Ratios: Symptom cases	Odds Ratios: Clinical cases
Low or medium physical hazard – composite index (versus none)	1.5	3.2
High job demands (versus low)	1.5	2.0
Psychological distress		
Medium (vs Low)	1.4	1.7
High (vs Low)	1.8	2.8

Huang et al (2003) obtained self-report, cross-sectional data from 289 US marines performing a variety of jobs. Odds ratios for the two strongest predictors of symptoms related to the back, to the upper extremities, and to both back *and* upper extremities were:

	Odds Ratios		
	Back	Upper Extremities	Both Back & UE
Biomechanical/physical hazard score (self-reports of 38 items)	2.1	1.8	2.8
Time Pressure	3.0	3.1	2.1

Johnston et al (2003) investigated predictors of new reports of low-back pain in a longitudinal study of 6311 'retail material handlers' (receivers/unloaders, stockers, managers) working at 160 stores of a large US chain. Data were collected by telephone interviews at baseline and six months later. Psychosocial predictor variables were obtained by factor analysis; results are shown below for the final regression model. The odds ratios for increases in low-back pain are not very large, but all are statistically significant:

	Odds Ratios
High job intensity	1.8
High scheduling demands	1.6
Job dissatisfaction	1.7
Lack of influence	1.2
Lack of security/decision au	1.2
Low supervisor support	1.4
Lifting 20lbs at work usually every day	1.2

Finally, Rugulies and Krause (2005) investigated predictors of low-back and neck injuries in a longitudinal study over 7.5 years of Californian bus drivers (final sample size = 1221). Injury data were obtained from insurance claims, and were defined as new cases occurring during the period of the study (post-baseline), controlling for previous pain levels and for physical workload (as well as the standard demographic variables as in all of these studies). Injuries arising from acute trauma (as opposed to cumulative) were excluded. Data from the Job Content Questionnaire (Karasek et al, 1998) was used to calculate 'job strain' (using scores for 'demand' and 'control') and iso-strain (using 'demand', 'control' and 'support' scores). For both Job Strain and Iso-Strain, upper and lower tertile scores were used to calculate hazard ratios (similar to odds ratios), and continuous scale scores were used to calculate effect sizes. Main results were:

	Low-back (tertiles)	Neck (tertiles)	Neck (continuous scales)
Job strain	HR = 1.3	HR = 1.5	1-point increase in Job Strain → 8% increase in risk of neck injury
Iso-strain	HR = 1.4	HR = 1.7	1-point increase in Iso-strain → 14% increase in risk of neck injury

In addition, it should be noted that there is evidence that at least some physical and psychosocial hazards can act synergistically in increasing WMSD risk (e.g. Bernard, 1997; National Research Council and Institute of Medicine, 2001; Devereux et al, 2004). Such interactions are inadequately understood and there is a clear need for more research on this topic. It is certainly true, however, that in many situations WMSD risk is highest when *both* physical and psychosocial hazard levels are at their highest.

In summary, the relative influence of physical versus psychosocial hazards on WMSD risk is variable, but *both* can have a substantial influence. It is therefore inappropriate for psychosocial hazards to be seen as necessarily secondary or peripheral to physical hazards – particularly in light of the accumulating evidence of biological pathways via which they can be *directly* involved in the development of injury. It can be concluded that control of both physical and psychosocial hazards is essential if WMSD risk is to be managed effectively.

3.2 From hazard identification to risk control requirements

Professional experts and researchers in this domain typically describe hazards in generic and so quite abstract terms such as ‘posture’, ‘biomechanical loading’, ‘static load’, ‘autonomy’, ‘cognitive demands’ and so on, as is evident from the literature summarised in the preceding section. Such terminology is used in Figures 5 and 6, and in the top three of the four factor categories in Figure 4. The competent interpretation and application of these fairly abstract terms during the process of identifying and assessing risks in specific workplaces requires quite a sophisticated degree of understanding. However, the great majority of people responsible for this task (including some occupational health and safety professionals) have little professional training *in this specific area*, and so lack such expertise.

Consequently, effective risk management – particularly the generation of effective risk control measures – is likely to require these generic and fairly abstract terms to be described in relation to the specific workplace factors that generate them – that is, ‘workplace features’ of the kind identified in the bottom layer of Figure 4. Thus, ‘posture’ and ‘static load’ need to be described in relation to the design of the concrete objects and specific actions that generate them, such as the design details of tools, workstations and the physical workplace environment (e.g. lighting levels), and in relation to the specific activities entailed in performing particular tasks. Similarly, terms such as ‘autonomy’ or ‘control’ might need to be understood in relation to specific aspects of work organisation and management, such as the extent to which people can vary their own pace of work and take breaks as required, or obtain additional resources to cope with peak loads, or modify deadlines, or vary their work performance strategies or overall pattern of job performance, or their workplace attendance and behaviour more generally.

An overview of the articles reviewed for this report is presented in Appendix A. In the case of physical hazards related to work activities or the environment, these articles address the issue of WMSDs directly. In the case of psychosocial hazards, however, there are many fewer articles that focus specifically on WMSDs, so examples from the wider literature establishing linkages between work-related hazards and fatigue or stress have also been included. It can be seen, from the relatively small number of entries in the first four columns of the table in Appendix A, that researchers do not often address the specific workplace factors underlying the more generic hazards that are usually the focus of research. Information about specific workplace factors, which is likely to be needed to support effective WMSD risk management by non-experts, is more likely to be found in national and international standards, codes and guidelines that are intended for use in preventing WMSDs, than in research literature.

The present authors recently analysed and critically evaluated the content of such documents (Macdonald et al, 2004), and some of the key findings from that report will be summarised here. The search was confined to English language documents that were available free, or already held by the researchers. On that basis, 33 documents were selected as representing good examples within a variety of sub-categories, and these were subjected to detailed analysis. It was evident that while sharing a common focus on one or more aspects of WMSD risk management, these documents could be subdivided into (1) those focusing on *hazardous activities* – including 'manual handling', or on particular types of hazard such as static postures, vibration, use of VDUs, etc; and (2) those focusing on *WMSD prevention* – either in general, or related to a particular body region, or associated with work in a particular industry. Some others, that were typically regulatory or legislative documents, addressed occupational health and safety more generally.

Information from these documents was summarised using a template that was developed on the basis of research evidence such as that reviewed above, to ensure comprehensive identification and assessment of all relevant hazards. The completed template is shown in Table 1; the shaded rows in the top half of the table (starting with the third row) represent the different types of WMSD hazards that should be identified and assessed.

The more detailed content of these are outlined in summary form below, including reference to both generic and specific workplace hazards within the following categories: (1) Physical task demands that may cause hazardous activities and/or hazardous personal states[4]; (2) Perceptual, cognitive and psychomotor task demands that may cause hazardous activities and/or hazardous personal states; (3) Overall job demands; (4) Physical environment; (5) Psychosocial environment; and (6) Employee characteristics. The main types of hazard within each of these categories are outlined below, followed by the associated kinds of specific *control* measures that are required to control WMSD risk.

3.2.1 Physical task demands

Some types and levels of physical task demands may cause the activities from which they stem to be hazardous, either directly, or by inducing one or more kinds of hazardous personal states (see footnote 5).

Such physical task characteristics include: dynamic and static load/force characteristics; postural demands/constraints, and repetitive activities. More specific details might include: heights and distances lifted; load characteristics; pushing and pulling forces; repetition of actions; awkward and static postures of different body parts and of whole body; types of hand grip; jerky actions; mechanical contact stress; repeated stepping up/down; jumping; squatting/kneeling; foot use.

Some of these factors need to be assessed separately for each body part, and information about possible interactions between these factors or with other factors (e.g. cold, individual anthropometric dimensions) should also be reviewed.

[4] *Hazardous personal state:* a non-permanent personal state that increases the probability of an injury to that person: either *directly* – e.g. stress; local muscle fatigue), or *indirectly* – e.g. general fatigue or other such states that reduce coping capacity and therefore increase the risk of performance errors and of stress. *Hazardous activity*: an activity that increases the probability of an injury to the person performing it: either *directly* – e.g. heavy lifting that directly causes tissue injury (acute or incremental), or indirectly by inducing one or more hazardous personal states (e.g. repetitive work, monotonous work, externally paced work).

Table 1. Summary of the coverage of WMSD hazards (shaded rows) and control guidelines (remaining rows) provided by a selected set of 33 international Standards, Codes and guidance documents relevant to WMSD risk management. *(from Macdonald et al 2004)*

	Australia: National Code of Practice for Manual Handling	Australia: National Code of Practice for the Prevention of Occupational Overuse Syndrome	Australia – Queensland. Manual Tasks Advisory Standard	Australia – Victoria. Code of Practice for Manual Handling	EC Directive 89/391 ...encourage improvements in the safety and health of workers at work	EC Directive 90/269/EEC ... manual handling of loads ... back injury ...	EC Directive 2002/44/EC ... risks from physical agents (vibration).	ISO 11228-1 Ergonomics - Manual Handling – Part 1	ISO/FDIS 6385:2003 Ergonomic principles in the design of work	ISO 11226 Ergonomics – Evaluation of static working postures	Japan: Guidelines on the prevention of Lumbago in the workplace	Netherlands Working Conditions Act	NZ Code of Practice for Manual Handling	NZ Approved Code of Practice for the use of Visual Display Units ...	NZ Occupational Overuse Syndrome Guidelines for Prevention	Norway Act Relating to Worker Protection and Working Environment	South Africa OHS Act
Document Overview	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓	✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓	✓	✓✓	✓✓
Initial ID/Assessment of Injury Problem	✓✓✓	✓✓	✓✓✓	✓✓✓	-	-	-	✓✓	-	✓	-	✓	✓✓✓	-	-	-	-
Hazard ID and Risk Assessment																	
Physical Task Demands																	
Shoulder, Back MSDs	✓✓✓	✓✓✓	✓✓✓	✓✓✓	-	✓✓✓	✓✓	✓✓	-	✓✓	✓✓	-	✓✓✓	-	✓	-	-
Elbow, Arm Wrist, Hand MSDs	-	✓✓	✓✓✓	✓✓✓	-	-	✓✓	-	-	✓✓	-	-	✓✓	-	✓✓✓	-	-
Feet, Legs, Knees, MSDs	-	-	✓✓✓	✓	-	-	-	-	-	✓✓	-	-	✓	-	✓	-	-
Perc-Cog-Motor Task Demands	✓	✓	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-
Overall Job Demands	✓	✓✓	✓	-	-	✓✓	-	-	-	-	✓	-	✓	-	✓✓	-	-
Physical Environment Hazards	✓✓	✓✓	✓✓	✓✓	-	✓✓	-	✓✓	-	-	✓✓	-	✓✓✓	-	✓✓	-	-
Psychosocial Environment Hazards	✓	✓✓	✓✓✓	-	-	-	-	✓	-	-	-	-	✓✓	✓	✓✓	-	-
Interactions	✓	-	-	-	-	✓	-	✓	-	-	-	-	-	-	-	-	-
Employee Characteristics	✓✓	✓	✓✓	✓	-	✓	-	✓✓	-	✓	-	✓	✓	✓	✓	-	-
Hazard and Risk Control																	
Process	✓✓	✓	✓✓	✓	-	-	-	✓✓	-	-	✓	✓✓✓	✓✓	✓	✓	-	-
Control Hazards – Physical	✓✓✓	✓✓	✓✓✓	✓✓	-	-	-	✓✓	-	✓	✓✓✓	-	✓✓	✓	✓✓	-	-
Control Hazards – Perc-Cog-Motor	-	-	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-
Control – Overall Job Demands	-	✓	✓✓	✓	-	-	-	✓	-	✓	✓	-	✓	✓	-	-	-
Control – Psychosocial Environ.	-	✓	✓	✓	-	-	-	-	-	✓	-	-	✓✓	✓✓	-	-	-
Control – Physical Environ. Hazards	-	-	✓✓	-	-	-	-	✓	-	-	✓✓	-	✓✓✓	✓✓	-	-	-
Interactions	✓✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Consider Employee Characteristics	-	✓✓	✓✓✓	✓✓	-	-	-	✓✓	-	-	✓	✓✓	✓✓	✓✓	✓	-	-
Managing MSDs		-	✓✓	-	-	-	-	✓	-	-	-	-	✓✓	-	-	-	-

✓✓✓ - extensive coverage ✓✓ - moderate coverage ✓ - minimal coverage - – zero coverage

	Spain Regulations AND Technical Guide for the prevention of risks associated with manual load handling	Spain Regulations AND Technical guide … risks associated with the use of … visual display units	Sweden Ergonomics for the prevention of musculoskeletal disorders AFS 1998:1 *Provisions*	Sweden Ergonomics for the prevention of musculoskeletal disorders AFS 1998:1 *General Recommendations*	Sweden AFS 2001:1 Systematic Work Environment Management	UK Manuaal Handling Operations Regulations	UK Upper Limb disorders in the workplace	UK Healthe and Safety (Display Screen Equipment) Regulations	UK Aching arms (or RSI) in small business	UK Manual Handling Assessment Charts	USA - NIOSH Simple solutions: ergonomics for farm workers	USA – OSHA Ergonomics for the Prevention of MSDs. Guidelines for Poultry Processing	USA California. Easy Ergonomics. A practical approach for improving the workplace.	USA - California. Fitting the task to the person: ergonomics for very small business.	USA - Washington. WAC 296-62-051, Ergonomics	USA - Washington. Fitting the job to the worker: an ergonomics program guideline.
Document Overview	✓✓	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓✓	✓✓	✓	✓	✓	✓✓✓	✓✓	✓	✓✓✓	✓✓✓
Initial ID/Assessment of Injury Problem	✓	✓	-	✓✓✓	✓✓	-	✓✓✓	-	✓	-	✓✓	✓✓	✓✓	-	✓✓	✓✓✓
Hazard ID and Risk Assessment																
Physical Task Demands																
Shoulder, Back MSDs	✓✓	-	✓	✓✓✓	-	✓✓	✓	-	-	✓✓	✓	✓✓	✓✓✓	✓✓	✓✓	✓✓
Elbow, Arm Wrist, Hand MSDs	-	-	✓	✓✓✓	-	-	✓✓✓	-	✓✓	-	✓	✓✓	✓✓	✓✓	✓✓	✓✓
Feet, Legs, Knees, MSDs	-	-	✓	✓✓✓	-	-	-	-	-	-	-	-	✓	✓	✓✓	✓✓
Perc-Cog-Motor Task Demands	-	✓✓	✓	✓✓	-	-	✓✓	-	-	-	-	-	✓	-	-	-
Overall Job Demands	✓	✓	✓	✓✓	-	✓	✓✓	-	✓	-	-	-	✓	-	-	-
Physical Environment Hazards	✓✓✓	✓✓	✓	✓✓✓	-	✓✓	✓✓	-	✓✓	✓✓	✓	✓	✓✓	✓	✓	✓
Psychosocial Environment Hazards	✓	✓✓	✓	✓✓	-	✓	✓✓✓	-	✓	-	-	-	✓	-	-	✓
Interactions	-	-	-	✓	-	-	✓	-	-	✓	-	-	-	-	✓	✓
Employee Characteristics	✓✓	✓	-	✓✓	-	✓	✓✓	-	✓✓	-	-	✓	✓	-	✓	✓
Hazard and Risk Control																
Process	✓	-	-	✓	✓✓✓	-	✓✓	✓✓	✓	-	✓✓	✓✓✓	✓✓	-	✓	✓✓
Control Hazards – Physical	✓	✓✓	-	✓✓✓	-	-	✓✓✓	✓	✓✓	-	✓✓	✓✓✓	✓✓✓	✓✓	-	✓✓✓
Control Hazards – Perc-Cog-Motor	-	✓	-	-	-	-	✓	✓	-	-	-	-	-	-	-	-
Control – Overall Job Demands	✓	✓✓	-	-	-	-	✓✓	✓	✓	-	✓	✓	✓	-	-	✓
Control – Psychosocial Environ.	✓	✓	-	✓✓	-	-	✓✓	✓	✓	-	-	-	-	-	-	-
Control – Physical Environ. Hazards	✓✓	✓	-	✓	-	-	✓✓	✓	✓	-	-	✓	✓✓	-	-	✓✓
Interactions	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Consider Employee Characteristics	-	✓✓	-	✓	-	-	✓✓	-	-	-	-	✓	✓✓	✓	-	-
Managing MSDs	-	✓	-	-	✓✓	-	✓✓✓	-	-	-	-	✓✓	✓	-	-	-

Risk control measures for the above hazards should ensure that, to the maximum extent possible:

- distances lifted are minimised, and vertical lifts are centred around waist height
- load characteristics facilitate easy handling
- twisting of the trunk, particularly with high accelerations or decelerations, is minimised
- jerky actions are avoided
- mechanical contact stress is minimised
- hand-arm vibration (typically stemming from use of some power tools) is minimised.

Risk levels associated with the above factors should be evaluated in light of possible interactions between factors both within and between different categories (e.g. postures, forces, cold environment).

In summary, the above kinds of risk control measures should ensure that:

- Whole-body postures that deviate from neutral sitting or standing positions do not have to be maintained for extended periods, particularly in combination with static load or the exertion of force.
- Joint postures (particularly wrist, shoulder, elbow, neck) that deviate from neutral positions do not have to be maintained for extended periods, particularly in combination with static load or the exertion of force
- Static postures in any position (including ‘neutral’ sitting and standing) do not have to be maintained for extended periods of time.
- Required forces to be exerted and loads to be sustained are not excessive, taking account of the body part used, frequency and duration.
- Required degree of repetition of any specific types of action is minimised, particularly in combination with non-neutral postures, exertion of force, or exposure to hand-arm vibration.

3.2.2 Perceptual, cognitive and psychomotor task demands

As in the case of physical demands, these kinds of demands can (depending on their levels) cause the activities from which they stem to be hazardous (e.g. by exceeding an individual’s maximum possible rate of information processing, so that performance errors become inevitable), and/or they may result in hazardous personal states with additional flow-on effects on risk level (e.g. see Proctor and Van Zandt, 1994; Macdonald, 2003).

This category of WMSD hazards encompasses task characteristics likely to affect the mental effort and the time required for task performance, and consequent levels of fatigue and stress. Specific items include demands for: careful perception (e.g. for 'inspection' work to detect faults); both speed and accuracy; concentration; precise movements; task cycle time; work rate; perceived importance of avoiding errors in view of their perceived consequences.

Risk control measures for the above hazards include changes to the task, workstation, job or environment so as to ensure that:

– sensory/perceptual task demands are not excessively high
– psychomotor demands are not excessively high
– task cycle time is not excessively short
– overall level of mental demands is optimised in relation to individual characteristics (these should *not* be minimised since the resultant work would be undesirably boring)
– required performance standards are communicated to workers with sufficient clarity and detail, and adequate performance feedback is provided
– the required mean work rate or target output is optimised in relation to time required to achieve the required standard of performance
– the perceived importance of avoiding errors (criticality of consequences) is managed in a way that supports optimal speed/accuracy trade-offs
– there are no incompatible demands for maximum levels of *both* performance speed and accuracy concurrently
– task variety, and the frequency and duration of rest breaks, are sufficiently frequent to enable good concentration.

3.2.3 Overall job demands

Excessive job demands may induce hazardous personal states such as stress and chronic fatigue, which in turn may increase the probability of performance errors to such a degree that some activities become hazardous.

One of the most important of such demands is the overall *duration of working hours.* Quite apart from the risk that may be created by excessively long working hours via their effects on fatigue and possibly stress, this factor is likely to increase the durations over which workers are exposed to *other* hazards, with consequent increases in risk from those other hazard sources.

Also included here are factors that may affect levels of effort, fatigue and stress levels, such as excessively large amounts of work to be completed within the time available, rest breaks, task rotation patterns, shift rotations – particularly when night shifts are involved, and so on.

Risk control measures for the above hazards include changes to job design or work organisation to ensure that:

- the routine procedures used to organise work (e.g. setting production targets or standard work rates), to design jobs (e.g. task rotations, rest breaks, shift systems), and to supervise and manage workers more generally, take account of normal human capacities, limitations; values and preferences
- working hours are not excessively long, particularly if they entail some night shifts, in order to control:
    - total cumulative exposure to hazards of all types
    - fatigue levels, and possible flow-on effects on stress;
- frequency and duration of rest breaks are sufficient to avoid excessive fatigue (both physical and mental) and possibly consequent stress, particularly for work that is:
    - fast and/or physically strenuous
    - repetitive
    - monotonous;
- task variety is sufficient to maintain interest and job satisfaction (e.g. by rotating between different types of tasks), and to avoid stress due to excessive monotony and/or under-utilisation (or development) of individual skills.

3.2.4 Physical environment hazards (direct and latent) and risk factors

These include those aspects of the physical environment that may affect WMSD risk, whether directly, indirectly, or both – for example, whole-body vibration; having to work confined spaces, or in the cold or in heat/humidity; high levels of wind or noise; inappropriate lighting levels; and floor surface characteristics.

Risk control measures for the above hazards include changes to the workplace environment to ensure that:

– there is minimal or no exposure to whole-body vibration
– there is minimal or no exposure to working in:
    - confined spaces
    - extreme cold
    - extreme heat/humidity; high winds
    - high noise levels
    - uneven, slippery and sticky floor surfaces (particularly when the work requires walking around)
    - very hard floor surfaces for work that entails long periods of standing
– lighting levels are optimised and glare is avoided, to ensure that all necessary information can be seen easily and so reduce people's tendency to adopt hazardous postures (craning forward in order to see better).

3.2.5 Psychosocial environment hazards and risk factors.
These include specific items appropriate to the environment within the following three categories: low *control*, e.g. due to work performance being 'paced' by a moving assembly line or machine process time; low *social support;* low *instrumental support*.

These factors may affect WMSD risk directly (e.g. low control decreases the probability of obtaining adequate rest breaks in accord with individual needs, which may directly result in excessively high levels of local muscle fatigue), as well as more indirectly via their influence on stress levels.

Risk control measures for the above hazards include changes to the work organisation, job design, supervisory and management system and more general psychosocial 'climate' to ensure that:

– workers are able to manage their own performance in ways, and at a level, which avoids both excessive fatigue and stress:
– individual autonomy and control are optimised, as appropriate to the nature of the work and workplace;
– levels of supervisor and management support are perceived by workers as adequate, both in terms of adequate equipment and resources, and interpersonally

– there are adequate opportunities for people to experience social support from coworkers.

3.2.6 Employee characteristics associated with potentially hazardous personal states. This includes individual states of stress, fatigue, and/or overall wellbeing (such as could be routinely documented by an ongoing health surveillance system).

Risk control measures for the above hazards include:

– appropriate job selection and placement strategies to enhance the initial person-job 'fit'
– opportunities for workers to maintain and enhance their knowledge and skill levels, such as training to enhance employees' performance capacities (e.g. to increase proficiency in work-related skills, and to expand future career prospects; or to increase the ability to recognise relevant hazards within their own work activities and environment, and to take appropriate risk control actions)
– policies to assist individual workers to optimise their balance between work and non-work demands and stressors.

The above account of WMSD hazards is in as concrete and specific a form as is practicable for a description as this generic level – that is, for a description that is not adapted to describe the situation for a particular type of job or industry. However, as discussed in Section 5.4 below, this level of detail may be inadequate to support effective risk management by non-experts.

4. HAZARD IDENTIFICATION AND RISK ASSESSMENT METHODS

This ultimate purpose of the present project is to develop and trial more effective risk management methods for WMSDs, and in this section of the report, a selection of existing hazard identification and risk assessment methods are reviewed. These are summarised in table 2.

4.1 Overview of methods

Complex methods that clearly require significant expertise, *and that are not amenable to simplification*, have been excluded from consideration here because the main focus of this project is on risk management methods that are either already being used – or that have apparent potential to be amended and made usable – by non-experts in ordinary workplaces. In the case of methods assessing physical (as opposed to psychosocial) hazards, distinguishing clearly unsuitable methods from those with the *potential* to be amended for wider use was sometimes difficult; in doubtful cases, the strategy at this stage has been to include rather than to reject.

In Table 2, information about these methods is categorised based mainly on the type of WMSD hazard(s) being assessed. The categories used are:

- postures and loads (emphasis on posture)
- loads & associated hazards (emphasis on load)
- repetitiveness and associated hazards
- wider range of physical hazards
- both physical and psychosocial hazards
- psychosocial hazards
- adapted for specific jobs or industries, and finally,
- measures of stress and fatigue (hazardous personal states – see Figure 6).

The final category above was included in accord with the conceptual model shown in Figure 6 and discussed in section 3 above.

Table 2. Hazard identification and/or risk assessment methods that appear to be suitable for use by non-experts in ordinary workplaces, OR that have apparent potential to be amended and made usable in this way (as required for Stage Two of this project). *NB: Numbers in the 'Key References' column refer to the numbering of articles and reports summarised in Appendix A.*

Method and brief outline of how used	Hazard(s) Assessed	Information produced / Context	Key Refer'cs	Evidence of validity, reliability, sensitivity
A. METHODS FOCUSING ON POSTURE AND LOAD *(emphasis on posture)*				
OWAS – analyst ratings of observed postures	Assesses risk due to posture: 84 whole body postures (7 leg x 3 arm x 4 back) x 3 loads (0-10, 10-20, 20+kg). Sampled at regular intervals (e.g. 10s) – total of 100-120 per phase according to nature of the work – per work 'phases' (tasks)	Degree of risk (4 levels)	137, 93,94,95, 96,97, 98	Development and initial evaluation by expert panel; widely used and reasonable evidence of some reliability as posture measure. Evidence of validity of risk categories less clear.
PATH (Posture, Activity, Tools, Handling) – extension of OWAS)	Describes work activities and exposure durations to limited set of physical task demands: subset (8) of OWAS postures, forces greater than 44N but each posture includes info on activity component, plus tool use, and objects/materials being handled. Sampling clearly defined and well based. Need for sampling of 1-2d for least variable jobs, 5-6d for most variable.	Documents durations of particular task components and its demands – does not produce an overall risk score.	2, 190	Bootstrap re-sampling used to check reliability.
RULA – analyst ratings of observed postures	Assesses risk due to postures: focus on upper body (shoulder, elbow, wrist, wrist twist, neck, trunk, legs – between 2 and 4 categories each, some with additional weightings for awkward postures), load (0, 0-2, 2-10, 10+kg). Sampling problematic – no guidance on number of samples, which are chosen by the analyst – focus on most extreme *or* longest duration	Degree of risk (4 levels)	169,99	Widely used and some evidence of reliability as posture description. Evidence of validity of risk categories less clear.
REBA – extension of RULA type of approach to whole body	Trunk, Neck, Legs, plus, bilaterally, upper arms, lower arms, wrists (scored 2-4 for each, with amendment for awkward postures), plus force (0-3) and coupling (0-3). Sampling problematic – dependent on analyst	Degree of risk (5 levels)	205	REBA is often quoted, but few studies in the refereed literature.
ISO 11226 – recommends maximum durations for static postures of specific joints	Trunk inclination, head inclination, shoulder/upper arm. Extreme joint positions. Decision tree involving posture and duration.	Specifies acceptable, not recommended, or acceptable provided time limit not exceeded	490	none stated

Method and brief outline of how used	Hazard(s) Assessed	Information produced / Context	Key Refer'cs	Evidence of validity, reliability, sensitivity
***B. METHODS FOCUSING ON LOADS AND ASSOCIATED HAZARDS** (emphasis on load)*				
HSE-MAC (Manual Handling Assessment Charts)	Assessment of risk using decision flow charts for each of: Lifting, Carrying, Team Handling. Separate components for each of loads, distances, postures, postural constraints, grip, floor surface, other environment. (0-3 or 0-4)	4 levels of risk	446	None stated
ISO 11228-1- lifting and carrying; limits	Assessment of overall risk using a flow-chart decision tool involving postures, loads, frequency, duration, cumulative load (over shift)	3 levels: acceptable; acceptable provided time limit not exceeded; unacceptable	491	None stated, (incorporates NIOSH LE as part of assessment)
NIOSH LE - Lifting and lowering	Assessment of overall risk, taking account of loads, distances, postures, rate, duration each generate a numeric "multiplier"	Lifting Index is relationship between actual load and recommended weight limit (calculated)	207	Based on reference criteria (epidemiological, biomechanical, physiological, psychophysical)
Snook (Liberty Mutual) tables - lifting lowering carrying, pushing, pulling – application requires analyst estimates	Acceptable loads based on task parameters	Normative data on acceptability for various percentiles of population	206	Widely used – part of the basis for NIOSH LE. Snook claims 3x lowering of injury risk for jobs acceptable to 75% female population.
Borg estimate of force exertion – worker ratings	Assessment of grip force	CR-10 validated as an index of actual force exertion	57	Validated in relation to other physiological parameters
C. METHODS FOCUSING ON REPETITIVENESS AND ASSOCIATED HAZARDS				
OCRA Checklist	Assessment of duration and breaks, arm activity, hand force, awkward postures (unsupported, extreme ROM), cycle time, repetition rate, sudden movements *plus* local tissue compression, cold, inadequate gloves, slippery objects, rapid jerks or rebound shocks	4 levels of risk	60c	Few papers (but some conference presentations) involving its use
Latko method	Assessment of repetition (0-10) and speed of hand activity, "sensitive to exertion level and recovery time"	No risk criteria reported in this study – focused on method development	64	Preliminary validation in relation to measures of recovery time within job cycle, and recorded number of repetitions per second. Basis for ACGIH HAL.
ACGIH TLV for hand activity (HAL)	Assessment of repetition, peak finger force	3 risk levels: acceptable, intermediate, unacceptable	212	Main document not available to establish standing, but presentations to the 2006

Method and brief outline of how used	Hazard(s) Assessed	Information produced / Context	Key Refer'cs	Evidence of validity, reliability, sensitivity
				IEA conferences indicated emerging evidence of validity.
D. METHODS ADDRESSING A WIDER RANGE OF PHYSICAL HAZARDS				
PLIBEL – intended to identify work-related causes of pain/injury in specific body parts	Identifies (Y/N): postures (related to specific symptoms), physical work environment (physical); repetition, work organisation (breaks, control, time pressure, stress), vibration, jerks/shakes	Relationship between symptom location and likely posture / physical environment factors	191, 192	Linked to epidemiological literature; trialled with labour inspectorate. Validity and reliability tested. Starts from symptoms to identify likely causal factors.
Job Strain Index - to analyse jobs for risk of UE disorder	Assessment of perceived forces (cf Borg) (5), duration (%cycle) (5), repetition (5) and speed (5); hand-wrist posture (5); daily exposure (5). Multiplicative model.	SI score theoretically could range to >1000. Hazardous jobs 4.5-81, low-risk jobs 0.5-4.5. Suggest cutoff around 5-5.5.	62, 148	Data in food processing, multi-task version in process (IEA Maastricht)
ManTRA – Manual Tasks Risk Assessment	Assessment of daily duration (5 levels), repetition (5), force (5), speed (5) [force and speed combined as exertion (5)], awkwardness – deviations from joint mid-range (5), vibration – WBV or HAV (5)	Score 5-25. Suggested cutoffs for exertion (force and speed combined) – 5, sum of awkwardness and exertion – 8, combined risk score >=15	199	none stated
OPEL Bochum - New Production Worksheet	Assessment of working postures (standing, sitting, kneeling, lying); additional postural loads, forces (1-5 categories each) Forces and other load aspects (4 itemsx4 categories), MMH (complex rating and calculation), Special loads (3 items x 4 levels)	Score in each category	202	none stated
Self-report questionnaire	Y/N questions: durations of sitting and of mouse/keyboard (%s of total), and qualitative description of postures during computer use	Self reported posture and exposure compared with standardised and objective methods	188	Self-report was not reliable for either postures or duration of computer use
Washington Caution Zone Checklist	Screening (Y/N): 14 checks covering awkward posture, hand force, repetitiveness, repeated impact, heavy, frequent or awkward lifting, hd-arm vibration	Intended for screening checks by Inspectors	201	None stated
HSE-ULD in the workplace - Filter (simple ID checklist)	Screening (Y/N): Posture, forces, repetition, lifting, vibration, + regions of body-part discomfort.	Screening to ID need for further detail	447	None stated

Method and brief outline of how used	Hazard(s) Assessed	Information produced / Context	Key Refer'cs	Evidence of validity, reliability, sensitivity
Vic MH CoP - Screening tool	Screening (Y/N): repetitive or sustained postures, movements or forces (22 items); Duration; High forces (14 items); Employee experience (5 items); Environmental factors (incl. HAV or WBV) (9 items).	Intended for use by non-experts – Y/N	408	Widespread local use
Other Codes – see Table 1				
E. METHODS ADDRESSING BOTH PHYSICAL AND PSYCHOSOCIAL HAZARDS				
HSE-ULD in the workplace – full assessment (8 separate RA sheets) – primarily analyst ratings but some worker involvement	Screening (Y/N): separate sheets for: posture, forces, repetition, vibration, psychosocial factors (pacing, incentive payments, difficulty keeping up, support, overtime, attention/concentration, control, tight deadlines, training and information)	Suggested control options	447	None stated
QEC - Quick Exposure Check - worker questionnaire	Assessment of posture (back, shoulder/arm, wrist/hand, neck; loads, repetition, duration, exertion, visual demand, vibration, and some psychosocial hazards (difficulty keeping up, how stressful): 0-2, 0-3 (most), 0-4	Website gives scoring in each category.	194	Extensively tested concurrent validity, and reliability
WERC scales	Assessment of levels of an unusually comprehensive range of both physical and psychological task demands that *might* be hazardous are rated	Provides a detailed profile of task demand levels	195	No attempt has been made to link demand scores with overall risk level; reliability is also unknown
Mental Health Action Checklist	Work organisation; planning; working time arrangements; ergonomic work methods; workplace (physical) environment; mutual support at work; preparedness and care	Practical improvements in the workplace	198	none stated
Dutch Musculoskeletal Questionnaire	Description of work hazards (Y/N): qualitative task description, then assessment of hazards: monotony, control, variety, staffing, work schedule (work-rest regime), loads (static, dynamic), awkward/ constrained postures, repetitiveness, hand-arm vibration Health status and behaviours, stress, physical discomfort/pain, fatigue	Questionnaire responses – no summary risk measure	54	unknown
F. METHODS ASSESSING PSYCHOSOCIAL HAZARDS				
Business Health Culture Index (BHCI) – based on Demand-Control and Effort-	Assessment of risk using a short questionnaire: BHCI = group mean of 4 questions related to demand-control and effort-	Relationship of psychosocial hazards to WMSD	197	Manual details testing done in a number of settings

Method and brief outline of how used	Hazard(s) Assessed	Information produced / Context	Key Refer'cs	Evidence of validity, reliability, sensitivity
Reward models.	reward	symptoms.		
EEF Work Organisation Assessment Questionnaire – based on Cox and Griffith stress model.	Assessment of risk from psychosocial hazards: relationship with management, being valued, physical environment, workload issues. Plus assessment of 'a hazardous state: exhaustion' (scale from General WellBeing Questionnaire)	Intended for management of stress-related risks in manufacturing environments	55	Preliminary
COPSOQ Copenhagen Psychosocial Questionnaire – based on composite (Danish) stress model	Assessment of risk from multiple types of psychosocial hazard and hazardous states: constructs include demands, influence, development, control, and psychosocial environmental factors	Three versions for:: researchers, professional practitioners, workplace personnel	203	not stated, but probably exist
NIOSH Quality of Worklife Questionnaire – based on the widely used and well-validated NIOSH Generic Stress Questionnaire	Assessment of work-related psychosocial factors (42 items), culture, hazardous states and health, hours of work, work/family, supervision		33	
Job Content Questionnaire (JCQ): based on the Demand-Control-Support model – one of the most widely used and best validated means of assessing psychosocial hazards for stress-related health problems, but has rarely been applied specifically in assessing WMSD hazards. The following sample of publications used modified forms of the JCQ, or only some sections of it.				
Parts of JCQ, plus measure of stress	psychosocial hazards	Keyboard operators; Test/retest	139	
abbreviated JCQ	physical and, psychosocial hazards	general working population, mass survey	141	
modified JCQ	psychosocial hazards	Interaction of biomechanical and psychosocial factors	82	
abbreviated JCQ	standard hazards	Prevalence of LBP; mass survey	88	
JCQ plus items from numerous other questionnaires;	Psychosocial hazards and strain. Low support found significant	Prospective study of LBP	90	
Questionnaire including some JCQ items and some NIOSH Generic Stress Questionnaire	Psychosocial hazards	Longitudinal, psychosocial factors and LBP	1, 77	

Method and brief outline of how used	Hazard(s) Assessed	Information produced / Context	Key Refer'cs	Evidence of validity, reliability, sensitivity
G. METHODS ADAPTED FOR SPECIFIC JOBS OR INDUSTRIES				
Handling People - Qld	Mainly physical factors specific to patient handling; postures (back, neck, arms/shoulders, hand/wrist, legs, standing), repetition and duration, workplace design,. work environment, client characteristics work organisation (workload, isolation, shift duration, variety)	Checklist Y/N	416	no background stated
Building Industry	Mainly physical factors: discomfort/pain, workplace layout, working posture (above shoulder, back postures, awkward), jerky movements, extreme ROM, duration and frequency, location of loads, weights and forces, work environment, work organisation (availability of people, equipment, maintenance, bottlenecks)	Checklist Y/N	482	no background stated
Mining Industry	physical factors specific to mining (loads, load location, work environment), work organisation (workflow, staffing levels, reporting systems, maintenance). Emphasis on 'manual handling', whole-body vibration	concentrating mainly on controls	481	References
Office work (Worksafe Victoria 'Officewise')	Extensive office safety checklist physical factors and job design	Checklist directs user to possible advice on controls	480	References
Mining industry	Participatory process involving description of activities, document bodypart discomfort, brainstorming – simultaneous identification of hazards/risks and related controls	Focus on identifying control measures – no formal risk assessment	176	not stated
Data and word processing, data entry – intensive computer use	Macroergonomics, participative approach: wide variety of methods employed – documented discomfort (15Q) postural hazards (7Q), workstation description, plus psychosocial hazards	Action research approach – aimed at iterative solutions, not specific risk assessment.	84	none reported

Method and brief outline of how used	Hazard(s) Assessed	Information produced / Context	Key Refer'cs	Evidence of validity, reliability, sensitivity
H. METHODS ASSESSING HAZARDOUS PERSONAL STATES: STRESS AND FATIGUE				
'Stress' measures: There are many such measures, some of which are included in the above section on Methods Assessing Psychosocial Hazards (specifically, in *EEF, COPSOQ,* and the *NIOSH QWL*), as well as in the more comprehensive *Dutch Musculoskeletal Questionnaire*.				
Wornout/Exhaustion scale from the General Well-being Questionnaire (GWBQ)	Ratings of affective states related to cognitive fatigue.	Assesses this hazardous state in terms of norms or evaluates interventions	200	Validated, but risk levels not specified
Nordic Musculoskeletal Questionnaire	Presence and severity of physical discomfort or pain	Survey – no risk score.	211	
Body-part Discomfort	Rating or ranking discomfort or pain in specific body locations.	Evaluates time-based trends, interventions; risk levels not specified.	210	Widely accepted as a predictor of WMSD risk
Swedish Occupational Fatigue Index (SOFI)	Ratings of 5 dimensions of fatigue: lack of energy, physical exertion, physical discomfort, lack of motivation, sleepiness	Evaluates time-based trends, interventions; risk levels not specified.	196	Validated, but risk levels not specified

4.2 Specific deficiencies and more general issues related to existing methods

Reviewing the content and types of methods presented in Table 2, some general conclusions emerge.

4.2.1 Identification versus Assessment

First, it is noteworthy that quite a few of the methods included in Table 2 entail *only* identification, typically using a procedure that simply requires the user to tick a series of boxes to indicate whether each of the specified hazards is present or absent, *without* any assessment of the degree of associated risk – either specific to each hazard or overall risk. Such methods are: PLIBEL, the Washington Caution Zone Checklist, both of the HSE-ULD checklists, the Vic MH CoP (along with other such documents in Table 1), the Mental Health Action Checklist, the Dutch Musculoskeletal Questionnaire, and all of the industry-specific methods in Section G of Table 2.

In fact, the most widely used kind of WMSD risk management methods in Australia are checklists (of the type referred to in the above paragraph) from one of the Manual Handling Codes; these are intended to be used in conjunction with information about methods of risk *control* for the kinds of hazards being identified. In addition, some Codes (e.g. the Victorian one) provide a list of risk *assessment* methods. For example, the Victorian Code of Practice (WorkSafe Victoria, 2000b), in an Appendix on "Further advice", lists the following methods as suitable for further assessment *by an expert*, following use of the checklist:

- 2DSSPP (Michigan 2D Static Strength Prediction Program)
- 3DSSPP (Michigan 3D Static Strength Prediction Program)
- NIOSH 1991 (National Institute of Occupational Safety and Health Lifting Equation)
- 'Snook' tables (Liberty Mutual Manual Materials Handling Tables)
- OWAS (Ovako Working Posture Analysis System)
- RULA (Rapid Upper Limb Assessment)
- FWAP (Fine Detailed Work Action and Posture task analysis).

Of these, only the Snook tables, OWAS and RULA have been included in Table 2 above, since the others are considered unsuitable to be adapted for use by non-experts.

In light of the predominant role of hazard *identification* checklists, it can be assumed that very little formal *risk assessment* occurs in most Australian workplaces – notwithstanding that the process of hazard identification and risk control using one of the common checklists is widely referred to as "manual handling risk assessment". In fact, formal risk assessment appears to be relatively infrequent even among occupational health and safety professionals, including ergonomists. It therefore appears that prioritisation of potential risk control measures is more often based on perceptions of the pros and cons of alternative forms of risk *control* than on the formal assessment of risk levels.

4.2.2 Overall balance and comprehensiveness of coverage

In this section, the content of current hazard identification and risk assessment methods is reviewed in more detail, in relation to the evidence about specific hazards and their contribution to WMSD risk as outlined in Section 3.

Considering first the methods presented in Table 2, it can be seen that physical hazards are addressed much more commonly and comprehensively than are psychosocial hazards. This situation certainly does not reflect an absence of potentially suitable methods for assessing psychosocial hazards, since many generic methods are available.[5] However, it seems that these are not commonly being applied in the context of WMSD risk management. Review of generic methods of assessing psychosocial hazards is beyond the scope of the present report (since this focuses more specifically on assessment methods *specific to WMSD* risk management) but generic methods will not be excluded from further consideration at a later stage of the project.

The methods for assessing psychosocial hazards that were selected for inclusion in Table 2 (Category F) are those whose use has been recently reported in the context of WMSD risk management. The most commonly used of these is the Job Content Questionnaire (JCQ), in whole or in part), which is based on the Demand-Control(-Support) model of stress. Next most frequently reported is the NIOSH Generic Stress Questionnaire[6] (some sections or items), and the COPSOQ (Copenhagen Psychosocial Questionnaire) is rapidly gaining in popularity.

The most recent of the methods in this category of the table are the EEF Work Organisation Assessment Questionnaire, developed in the UK by the Engineering Employers Federation – EEF) specifically for use in manufacturing types of work environment, and the BHCI (Business Health Culture Index) from Canada. The EEF Questionnaire is based on a transactional model of occupational stress (see Cox and Griffiths, 1995; 1996). The BHCI is a very brief questionnaire (only four items) that appears to have excellent potential for use in the context of WMSD risk management, at least for initial screening to identify the existence of ‘psychosocial’ types of hazard; it is partially based on the Demand-Control stress model that underpins the JCQ.

As discussed in Section 3, the term ‘psychosocial hazards’ is often used in such an inclusive sense that it encompasses virtually all non-physical hazards, including hazardous personal states such as stress and fatigue. However, in the conceptual framework developed for this project (see Figure 6), psychosocial hazards are separated into sub-categories, with hazardous personal states differentiated from other sub-types. Accordingly, this type of WMSD hazard is presented separately in Table 2, as Category H.

Looking just at the coverage by current methods of physical hazards, it is evident that overall coverage is very uneven, with dynamic load and whole-body posture being the most commonly

[5] For example, see articles in most issues of the journals *Work and Stress*, or *Journal of Occupational Health Psychology*
[6] The very newly developed NIOSH Quality of Worklife Questionnaire is expected to supercede the NIOSH Generic Stress Questionnaire.

addressed.[7] Fewer methods are available to assess the degree (as opposed to simply identifying the presence) of risk associated with highly repetitive movement patterns, awkward wrist postures and hand activities. Further, while *sustained* postures and *static* loads are sometimes included on checklists, they are seldom assessed; and the situation is even worse in the case of risk due to high angular velocities of trunk bending and rotation, which is rarely even mentioned on checklists. Finally, the possible role of vibration – whether whole-body or hand-arm – is often given some cursory mention but rarely assessed.

The need for better methods of assessing risks associated with *repetitive movements* has recently been receiving more attention. This hazard is at least *identified* by most of the more recently developed methods that address a wide range of hazards (Categories D and E in Table 2). In addition, some new methods have recently been developed specifically to assess to assess risk related to work entailing highly repetitive movements of the arms and/or hands. Those included in Table 2 (Category C) are the OCRA Checklist (which is a simpler version of the more complex OCRA method). The other two in this category focus on hand activities; the more recent of these – HAL (Hand Activity Level), developed by the ACGIH, appears to have superceded the Latko method.

In the case of angular velocities of trunk movements, Marras and colleagues (e.g. 1998) have found, using their using Lumbar Motion Monitor method, that high velocities are among the best predictors of back injury. The expensive technological requirements of this assessment method has precluded its more widespread use, but current research by Koripas based at La Trobe University (publication of Masters thesis expected 2007) has demonstrated high correlations between Lumbar Motion Monitor data and observer ratings of trunk velocities for the same task. This research holds promise for the future development of more practicable methods for assessing risks associated with angular velocities of trunk bending and rotation.

Another type of hazard for which risk is less often assessed is wrist posture (flexion/extension, deviation). Of the methods included in Table 2, the only ones to *assess* this risk are the following: OCRA Checklist, Strain Index, ManTRA, RULA and REBA. The OCRA Checklist and ManTRA also assess hand (or hand/arm) activity, along with the ACGIH TLV Hand Activity Level (HAL) method and its predecessor developed by Latko, although they vary considerably in

[7] The NIOSH Lifting Equation is the mostly widely used means of assessing risk associated with this combination of hazards, with its use being incorporated within the design of some other methods such as ISO 11228-1 and others that were not included here because of their greater complexity.

terms of their focus of assessment (e.g. speed of movements, pinch grip force, large grip span and use of gloves).

Vibration is a fairly easy hazard to identify but, like angular velocities, it is usually assessed (if at all) using specialist equipment. Among the methods in Table 2, vibration is included on some general hazard *identification* checklists (e.g. HSE-ULD, Washington 'Caution Zone', Victorian Manual Handling Code of Practice) and in a checklist developed for use in the mining industry where vibration is widely recognised as an important hazard. However, only the recently developed ManTRA method goes beyond identification to *assess* vibration.

Given the centrally important role of simple checklists in most Australian workplaces (as discussed in 4.2.1), it is particularly important that they provide comprehensive and well-balanced coverage of the main WMSD hazards. Only a few of these documents were included in Table 2, but the content of the best available international examples of such documents is summarised in Table 1. It can be seen there (in the shaded section that deals with hazard identification and risk assessment) that their general content reflects the same pattern as in Table 2. It can therefore be concluded that the methods currently being used most widely (simple identification or screening checklists), as well as the methods currently available for risk assessment are focused mainly on just a *subset* of physical task demands and associated hazards, and they provide extremely little coverage of psychosocial hazards.[8]

This imbalance in the content of both WMSD hazard identification checklists and risk assessment methods indicates that such methods lag substantially behind current research evidence concerning the nature of WMSD hazards and associated risk levels (as summarised in Section 3). Current practice still largely reflects the state of knowledge up until the late 1980s and early 1990s, when the assumed causes of 'manual handling' injuries related to heavy lifting, with inadequate recognition of risks presented by static postures and repetition. During the 1990s these latter factors began to receive greater attention within national codes and guidance documents. The coverage of hazards is usually broader in documents that are specifically intended to address cumulative-onset WMSDs (e.g. National Health and Safety Commission, 1994), but even in these, the extent of coverage and level of detail relating to these latter types of hazard is small relative to coverage of heavy loads and awkward or demanding postures (refer to Table 1). These latter factors *can* be important contributors to cumulative WMSDs as well as to acute-onset

[8] The assessment methods discussed in this report are confined to those with potential for use by non-experts, but this conclusion is in fact true also of more complex methods that clearly require expert users.

injuries, but they are not *necessary* for the development of cumulative injuries, as discussed in Section 3.

Overall, then, risk assessment methods suitable for WMSD risk management do not provide adequate coverage of the multiple and potentially interacting causes of WMSDs. Their deficient coverage is most conspicuous in the absence of methods addressing psychosocial hazards *for WMSDs*. It is true that plenty of *general* methods are available for assessing people's stress levels, and that stress is a centrally important 'psychosocial hazard' for WMSDs; as depicted in Figure 6, it is a 'hazardous state' of individual workers. However, occupational risk management programs need to focus on the workplace hazards *causing* hazardous states such as stress. While some jurisdictions either have or are developing programs to manage work-related stress, these programs are typically applied in 'white collar' and 'professional' work environments where psychological injuries ('stress' claims) are a major problem, rather than in 'blue collar' and 'pink collar' environments where WMSDs are predominant. Since the form of psychosocial hazards is expected to vary considerably between 'white collar' and 'blue collar' environments, the hazard assessment and control methods for industry sectors with high levels of psychological injuries are unlikely to be suitable for use in environments where WMSD risk is the predominant issue.

4.2.3 Hazard exposure and 'dose'

Risk assessment provides some kind of measure of the overall level or risk presented by one or more hazards. Particularly in the case of cumulative injuries such as many WMSDs, assessment therefore requires consideration of hazard exposure *durations*, as well as hazard *severity* at a specific point of time, because overall risk is likely to depend on the *total dose* to which workers are exposed. At least in the case of physical hazards, *dose* is often taken to be determined by the hazard's average severity multiplied by the duration of people's exposure to it.

However, many WMSD hazards arise from the hazardous nature of people's *activities*, so that hazard severity may be highly variable throughout a work shift, to an extent depending on how repetitive their activities are. For jobs in which work tasks are varied and variable, this means that WMSD risk stemming from physical activities requires assessment over extended periods so that the work activities are adequately sampled. However, most WMSD assessment methods are of a brief 'snapshot' variety, typically giving far greater weight to the observed severity at just one (or a few) observed points in time. Further, most assessment methods have no adequate means of taking appropriate account of the effects on WMSD risk of varying *durations* of exposure, or of overall dose.

Considering the methods in Table 2, the only ones seriously to address the issue of exposure duration, albeit in quite variable ways, are: PATH, the OCRA Checklist, the Strain Index, ManTRA, the QEC and OWAS. However, the processes by which these methods combine risk assessments associated with specific hazards into an overall risk index for the whole activity are of largely unknown validity.

The OCRA Checklist takes account of absolute durations of work in relation to rest break durations, considered cumulatively through the work shift; however, its scoring system does not incorporate any means of taking account of work shifts longer than 8 hours. The Strain Index, ManTRA and the QEC take a simpler kind of approach based on a small number of duration categories; the Strain Index and ManTRA use five categories ranging from 1 hour or less up to 8+ hours; the QEC uses only three categories, from up to 2 hours through to 4+ hours. The approach taken by OWAS and PATH is different and likely to be more valid, but also much more time-consuming, being based on repeated observations of behaviour at pre-determined frequencies so that the most frequently occurring postures or activities (depending on the method) can be identified in terms of percentage of time spent within the whole work shift.

Duration is also taken into account by ISO 11228-1, ISO 11226 and the NIOSH Lifting Equation. In the latter, different limits are calculated for exposure durations during a shift of 1, 2, or 8 hours durations performing the analysed task, with the underlying assumption that no other activities performed during the shift make significant physical demands of a similar nature to the analysed task. Also, both the NIOSH LE and the Snook (Liberty Mutual) tables assume that work shifts do not exceed 8 hours.

Such assumptions are particularly problematic in the current Australian context, where working hours are among the longest of any industrially advanced country and work ‘intensification’ has become a prominent issue in recent years. Also, the minimal account taken by most methods of rest breaks in relation to work durations, both within and between work shifts, is of concern, because there is clear evidence that recovery from work-induced fatigue during rest and meal breaks is incomplete, so that fatigue accumulates over *at least* a working shift (Corlett & Bishop, 1976; Macdonald & Bendak, 2000). Also, there is evidence that fatigue and associated microdamage to muscle fibres can accumulate over the working week, and even longer periods depending on the nature of work-rest patterns (Hedberg & Niemi, 1986); Malcolm et al, 1995). It must be acknowledged here that the forms of relationships between WMSD risk, hazard severity and exposure duration may vary not only between different types of hazard but between different forms of WMSD, as discussed by Punnett and Wegman (2004), and that there is a need for medical scientists to conduct more research on these issues. In the meantime, however, from the viewpoint of occupational risk management, WMSD hazard assessments should incorporate some information about hazard exposure durations, with the form of such information and the means by which it is used in assessing risk being the subject of ongoing ‘action’ research.

Overall, it can be concluded that the deficiencies in current methods of WMSD hazard identification and risk assessment, as outlined above, present a very significant barrier to achieving more effective risk management. In the following section, some additional barriers are considered.

5. OTHER BARRIERS TO IMPROVED WMSD RISK MANAGEMENT

Over the past two decades, government authorities throughout the world have invested very substantial resources in addressing the problem of WMSDs – particularly in the development, and to a lesser degree (relative to the need) the enforcement of various workplace 'standards', codes and guidance documents. Australian jurisdictions have been at the forefront of these activities, internationally. However, there has not been a correspondingly substantial impact on the magnitude of this major occupational health problem. Although such codes and guidance documents are the primary means by which Australian workplace managers are expected to identify and control WMSD risk, they have been subjected to very little evaluation and there is very sparse evidence concerning their effectiveness in reducing WMSDs.

Boucaut et al (1994) reported on a study in which a panel of experts used the Worksafe Australia manual handling code of practice checklist to rank the risks of 23 tasks undertaken by firefighters. From the absence of correlations between these risk rankings and actual injury statistics, they concluded that the checklist does not succeed in assessing risk well enough to identify the highest risk tasks. In South Australia, O'Keefe and Furness (2001) reviewed that state's WorkCover Corporation Manual Handling Regulation and Code of Practice, acting in response to employer perceptions that it was neither user-friendly nor effective. Levels of reported WMSDs were no different in workplaces where people reported having used the Code than in those where it had not been used.

There has been remarkably little published discussion about *reasons* for the apparent (relative) ineffectiveness of current approaches to WMSD risk management, or about the means by which these could be enhanced. The most obvious kinds of barriers to improved risk management are deficiencies in the methods currently being used to identify hazards and assess the associated risks for WMSD; these were the subject of Section 4 of this report.

In the remainder of this section, other barriers to achieving substantial reductions in WMSDs are reviewed. Several such barriers were identified by Evans and Macdonald (2001) in a presentation to a conference of the Safety Institute of Australia, and they expanded these arguments in Issues Paper 1 of the NOHSC (National Occupational Health and Safety Commission, 2003a) *Review of the National Manual Handling Standard and Codes of Practice*. Following that review, another NOHSC paper entitled *Barriers to the Adoption of Safe Manual Handling Practices: A Literature Review* (National Occupational Health and Safety Commission, 2003d) also addressed this general question. From a UK perspective, Whysall et al (2004) presented findings from a small empirical investigation of the effectiveness of routine ergonomics consultancy interventions; while this is a somewhat different topic, its findings further substantiate the importance of some of the barriers identified in the preceding publications. Material from these sources is reviewed below.

5.1 Misleading terminology

Use of the term ‘manual handling’ injuries as a label for WMSDs is in itself a significant barrier to more effective risk management. This is particularly true when the term is used to label the standards, codes and guidance documents that for most people are the primary means of controlling WMSDs. Labelling the subject of these documents as ‘manual handling’ clearly implies that the injuries they are intended to prevent have purely physical causes. Further, since the term ‘manual handling’ is commonly understood by non-experts to imply lifting and carrying activities that involve the exertion of some force, use of this term tends to reduce the perceived hazardousness of *low*-force activities which in fact may be very hazardous *when performed for extended periods,* such as those entailing static or awkward postures, or repetitive, low-force actions.

These points were strongly made by several of the group of Certified Professional Ergonomists whose views were reported in the NOHSC 2003 *Issues Paper 1* as part of the Review of the National Manual Handling Standard and Codes of Practice (National Occupational Health and Safety Commission, 2003a). In the view of these experts, such terminology constrains people’s thinking about possible causes of WMSDs and results in much too narrow a concept of how WMSD risk should be managed. They argued that the definition of ‘manual handling’ in these documents departs so far from common usage that it presents a significant barrier to hazard identification by non-experts, (and even by professional practitioners whose expertise does not focus specifically on this topic), and it therefore hinders implementation of more effective injury countermeasures. These suggested that, rather than use terms such as ‘manual handling’ or ‘overuse’, it is preferable to use a term that does not imply a particular type of cause and which therefore does not hamper the process of hazard identification.

This point was also made strongly by Kuorinka and Forcier (1995, p.5), who argued that the term WMSD “better corresponds to the World Health Organization’s definition and concept of work related disease … [and] avoids the confusion of including both the postulated cause (e.g.

‘cumulative’ in CTDs or ‘repetitive’ in RSI) and the effect (‘disorder’ in CTDs or ‘injury’ in RSI) in the same term”. Similarly, MacFarlane et al (2000) of the University of Manchester Medical School, wrote that: “Misleading terms such as ‘cumulative trauma disorder’ or ‘repetitive strain injury’, implying a single uniform aetiology, should be avoided”.

5.2 Failure to adopt a ‘systems’ approach to risk management

Typically there are several major sources of risk associated with the occurrence of any given injury, and a very limited workplace budget for the development and implementation of risk control measures. In these circumstances it is important that *all* of the main risk sources are not only identified but their *severity levels assessed*, including consideration of the *total dose* to which workers in specific jobs are subjected, in order to support more effective prioritisation of control measures. Currently, the focus of most WMSD hazard identification, risk assessment and control methods is very much on specific *tasks*, but cumulative exposure or dose is determined by workers’ overall *jobs*.

On the importance of *cumulative exposure*, ergonomists from WorkSafe Victoria have commented that:

> “Both the current National Standard and Codes and the Victorian Regulations and Code focus on individual “tasks”. This makes it difficult to consider/demonstrate the cumulative risk of work which includes more than one task with similar risk factors, that individually may fall below any “threshold limit value”. Professional consultants may take this into account, but workplace parties who are following the letter of the law may decide there is not [a] risk even though the person is exposed for longer if all the relevant tasks are taken into account.” (National Occupational Health and Safety Commission, 2003a, p.14)

Evans and Macdonald (2001) argued that to obtain useful information about dose, risk needs to be managed much more proactively than is currently the case. In particular, managers need to establish more comprehensive and detailed databases that facilitate the investigation of *relationships* between a wide range of different hazards, hazardous states and health-related outcomes. Levels of all variables should be periodically assessed and records updated as a matter of normal routine. The resultant vastly improved database of OHS information would provide the means of developing a system for monitoring and controlling *cumulative* hazard exposure levels, as well as providing an effective means of evaluating and ‘fine tuning’ improved methods of risk control.

Very similar conclusions were drawn by another NOHSC report (National Occupational Health and Safety Commission, 2003d), in which identified barriers to the "adoption of safe manual handling practices" included "poor integration of risk management in business/service broader risk management system and processes" and "the absence of a musculoskeletal data surveillance and reporting system, along with health and hazard surveillance data collection".

Another important component of a 'systems approach' to WMSD risk management is an effective legislative enforcement program, to maximise compliance levels. The Commission of the European Communities (2002), in a report on 'Adapting to change in work and society: a new Community strategy on health and safety at work 2002-2006', says there must be

> "Better application of existing law: prevention services should be genuinely multidisciplinary, embracing social and psychological risks, and the gender factor. Labour inspection activities must be capable of appraising all the risks, particularly in those sectors where they tend to be complex and cumulative (e.g. hospitals)."

Further support for the necessity of a systems approach is provided by a recent study in the UK by Whysall et al (2004) concerning the effectiveness of routine ergonomics consultancy interventions. Based on interviews with 14 ergonomics consultants about their usual consultancy procedures and practices, perceived barriers to promoting change and the extent to which evaluation of outcomes occurs, the authors identified 'lack of a systems approach' as a major barrier to more effective interventions. Many of the ergonomists perceived *non*-physical factors as beyond their area of responsibility (contrary to formal definitions of ergonomics as it applies to occupational health and safety). Consistent with this, they generally lacked techniques for assessing risks associated with psychosocial hazards and hazardous personal states (in present terms), and they reported that their clients were generally unreceptive to anything other than a narrowly focused approach confined to the most widely recognised physical hazards.

This account of the overly narrow approach taken by ergonomists, at least partially in response to the narrow expectations of their clients, is echoed by the conclusions of Pransky et al (2002) concerning the very narrow perspective of physicians treating people with WMSDs. Based on a review of literature evaluating the effectiveness of intervention studies to reduce WMSDs of the upper extremities, they wrote that

> "Although physicians routinely explore the physical causes and manifestations of illness,

> there is much less acceptance of a routine, equally thorough exploration of mental aspects, when patients present with musculoskeletal conditions. Significant barriers include social undesirabiity of mental health-related conditions; lack of training, experience, and motivation of health care providers; and the limitations of current scientific evidence for stress-related interventions in WRUEDs.” (p.452)

A number of other barriers to more effective risk management were identified by Whysall et al (2004), including: *lack of senior management commitment* (lack of involvement in requesting and receiving consultancy advice, and little if any involvement in the consultancy process); and *poor uptake of recommendations by client organisations* (poor understanding of the rationale; perceptions of cost-benefit of recommended actions, particularly concerning preventative actions and large scale changes).

Perhaps most importantly in the present context, the authors pointed to: “... the tendency for organisations to implement changes themselves *and to select from the recommendations the least expensive or easiest changes*.” (Whysall et al, 2004; italics added). This supports the suggestion in Section 4 above that inadequate risk *assessment* (rather than just identification) is likely to lead to precisely this situation: in the absence of a comprehensive risk assessment, there is no reliable basis for identifying the potentially *most effective* kinds of control measures. The continuing widespread use of training in ‘safe lifting’ techniques, despite the position of this kind of risk control intervention at the *lowest* (least effective) level of the accepted ‘hierarchy of risk controls’ and the substantial amount of empirical evidence of its ineffectiveness (see following section), is testimony to the need to provide a more rational basis for the selection of risk control measures.

5.3 Inadequate adherence to the ‘hierarchy of risk control’

To promote the most effective use of available resources to prevent occupational injury, there is a generally accepted hierarchy of risk control measures, which places highest priority on the measures likely to be most effective. Variants of this hierarchy are inherent, if not specific, in the occupational health and safety legislation of most jurisdictions. The version of the hierarchy used by the International Labour Organisation (ILO-OSH, 2001, section 3.10.1.1) specifies the hierarchy as: (1) eliminate the hazard/risk; (2) control the hazard/risk at source, through engineering controls or organizational measures; (3) minimize the hazard/risk by the design of safe work systems, which include administrative control measures; and (4) where residual hazards/risks cannot be controlled by collective measures, the employer should provide personal protective equipment (PPE). All versions of the hierarchy place top priority on *eliminating* the hazard and lowest priority on controls that rely for their effectiveness on the behaviour of individual workers, such as use of PPE or ‘safe lifting’ training. However, as suggested above, there is evidence that this hierarchy is widely ignored.

The hierarchy only needs to be followed as far as is reasonably ‘practicable’, which typically includes consideration of the degree of risk (considering both severity and probability), current knowledge regarding the hazard and its risk, and the availability and costs of potential control methods. In the case of WMSD risk, training workers to improve their lifting or ‘manual handling’ *techniques* is often seen as a relatively quick and cheap method and therefore as highly ‘practicable’ ... while evidence of its general ineffectiveness as a means of reducing risk (see review by Hignett, 2003), and its low ranking within the control hierarchy, are ignored.

It should be noted, however, that while training in lifting techniques is highly unlikely to reduce injury risk, training in the hazard identification, risk assessment and control is another matter altogether – particularly if the training is for managers or system designers (Macdonald, 2005). Consistent with this, the NOHSC (National Occupational Health and Safety Commission, 2003d) report concluded that “training, as a risk control measure needs to be better integrated into a risk management system”.

5.4 Poor usability of risk management information and methods

Arguably, one of the reasons for the poor risk management practices noted above is that managers’ knowledge and understanding of occupational health and safety risk management principles is generally poor. It is therefore important that all methods and associated guidance materials that are intended for general use in WMSD risk management should be optimal in their content and designed to ensure easy usability by prospective – non-expert - users. In the case of ‘manual handling’ standards and related guidance material, a NOHSC report (National Occupational Health and Safety Commission, 2003a) summarised such issues and requirements, and one of its recommendations was that “A high priority should be given to developing greater numbers of *industry-specific* guidance documents” in order to improve their usability for non-experts. The advantage of such an approach is that it allows information to be communicated in more specific and concrete terms that are more likely to be familiar and understood, and therefore more likely to be used as intended.

In the present project, the focus is on risk assessment methods rather than guidance materials, but many of the same principles are applicable. Increasingly, hazard identification checklists (often incorporating some guidance on associated risk control options) are being developed for specific industries or job types, as illustrated in Category G of Table 2 (Section 4). O'Keefe and Furness (2001) supported the desirability of such methods, based on their review of reported difficulties in implementing the South Australian 'Manual Handling' Code. They concluded that guidance materials such as checklists are likely to be of greater practical value than more formal documents such as Codes or the Regulation(s), *particularly if their relevance is enhanced by tailoring to specific workplaces or industries*. (italics added)

On this basis it can be hypothesised that to support good understanding and usability for non-expert users, risk *assessment* methods must to some degree be adapted, as many *hazard identification* checklists have already been, to more directly match the kind of work and work environments where they are intended to be applied. One of the aims of the proposed second stage of this project is to investigate this question.

6. CONCLUSIONS

The present report constitutes the first part of a multi-stage project, the overall purpose of which is to develop and trial more effective risk management methods for work-related musculoskeletal disorders (WMSDs) that develop cumulatively. It has summarised contemporary research literature and other documented evidence concerning:

1. hazards that are most strongly predictive of the risk of work-related musculoskeletal disorders (WMSDs)
2. currently available WMSD risk management methods – including methods of identifying hazards and assessing risk levels, and general means of risk control
3. evidence concerning real or perceived barriers to the implementation of risk assessment and control measures.

Addressing the first of the above objectives, it was shown that cumulative WMSDs stem from workplace situations where there is substantial mismatch between one or more of a wide range of workplace factors and one or more personal factors, such that there is in an inadequate margin between the work demands that people have to cope with and the coping resources available to them. Excessive *physical* demands of various kinds can be directly injurious, while excessive demands of other kinds can result in injury by increasing the risk of hazardous personal states due to excessively high levels of fatigue and/or stress. Such hazards are listed below.

Hazardous task and job demands:

- Hazards related to the physical characteristics of task performance – particularly awkward or sustained postures, repetitive movements, static and dynamic loads or force exertions, hand-arm vibration, local tissue compression; such hazards can *directly* result in WMSDs – acute-onset as well as the cumulative-onset injuries that are the present focus
- Excessive amounts of work, long shifts, inadequate rest breaks, long weeks, time pressures, responsibilities, etc
- Inadequate time to cope with perceptual/ cognitive task demands
- Excessive emotional demands of the work

Inadequate resources for coping with work demands:

- Inadequate workplace support: poor materials/information, poor supervisor support, poor social cohesion, low morale, inadequate training provisions
- Physical environment hazards: whole-body vibration, cold

Other psychosocial hazards, such as:

– Inadequate personal control and autonomy
– Inadequate task variety and opportunities for skill utilization
– Inadequate job security

Low levels of individual resources in relation to task or overall job requirements: biological tolerances, inadequate skills and/or basic capacities or skills

Resultant hazardous personal state(s) of fatigue (varying types) and/or of psychological stress which entail physiological responses that directly increase injury risk.

Addressing the second objective, review of currently available WMSD risk management methods was focused on those that are either already being used – or that have apparent potential to be amended and made usable – by non-experts in ordinary workplaces. These were categorised as addressing:

- postures and loads (emphasis on posture)
- loads & associated hazards (emphasis on load)
- repetitiveness and associated hazards
- wider range of physical hazards
- both physical and psychosocial hazards
- psychosocial hazards
- adapted for specific jobs or industries, and finally,
- measures of hazardous personal states of stress and fatigue

It was noteworthy that the most commonly used methods are hazard *identification* checklists such as those from one of the Manual Handling Codes, and that very little formal risk *assessment* occurs in most Australian workplaces – notwithstanding that the process of hazard identification and risk control using one of the common checklists is widely referred to as “manual handling risk assessment”.

Reviewing the overall balance and comprehensiveness of coverage of hazard assessment methods, existing hazard identification and risk assessment methods were found to have some significant deficiencies when evaluated in relation to contemporary knowledge of the full range of WMSD hazards. The current failure to assess and control psychosocial hazards as part of WMSD risk management programs within high-risk industry sectors was identified as a particular problem.

Physical hazards are addressed much more commonly and comprehensively than are psychosocial hazards – whether those stemming from the work, job and workplace environment, or hazardous personal states of fatigue or stress. Focusing just on the *physical* hazards addressed by current methods, it was evident that dynamic load and whole-body posture are the most common focus of attention. Fewer methods are available to assess the degree (as opposed to simply identifying the presence) of risk associated with highly *repetitive movement* patterns, awkward *wrist postures* and *hand activities*. Further, while *sustained* postures and *static* loads are sometimes included on checklists, they are seldom assessed; and the situation is even worse in the case of risk due to high angular *velocities* of trunk bending and rotation, which is rarely even mentioned on checklists. Finally, the possible role of *vibration* – whether whole-body or arm-hand – is often given some cursory mention but rarely assessed. This overall imbalance in the content of both WMSD hazard identification checklists and risk assessment methods indicates that these methods lag substantially behind current research evidence of the nature of WMSD hazards and associated risk levels.

Despite the fact that risk assessment requires consideration of hazard exposure *durations*, as well as hazard *severity* at a specific point of time (when assessed), because risk is likely to depend on the *total dose* to which workers are exposed, particularly in the case of cumulative injuries, it was found that most WMSD assessment methods measures give just a brief 'snapshot', giving greater weight to the observed severity at just one (or a few) observed points in time than to exposure duration or overall dose.

Overall, it was concluded that the deficiencies in existing methods of WMSD hazard identification and more particularly, risk assessment, present a significant barrier to achieving more effective risk management.

Addressing the third objective, little published evidence was available concerning barriers to the implementation of effective WMSD control measures., but the following kinds of barrier were tentatively identified.

First, use of the term 'manual handling' injuries as a label for WMSDs is in itself a significant barrier to more effective risk management, particularly when the term is used to label the standards, codes and guidance documents that for most people are the primary means of controlling WMSDs. Use of this terminology such terminology constrains people's thinking about possible causes of WMSDs and results in much too narrow a concept of how WMSD risk should be managed.

Second, there is evidence of a widespread failure to adopt a broad and integrated ‘systems’ approach to risk management, resulting in a piecemeal approach in which the focus of most WMSD hazard identification, risk assessment and control methods is on specific *tasks*, whereas cumulative exposure or dose is determined by workers’ overall *jobs*. In the absence of such an approach, there is no reliable basis for identifying the potentially most effective kinds of control measures. Third, and related to the previous point, there appears to be inadequate adherence to the ‘hierarchy of risk control’, evident in too great a reliance on interventions such as training in ‘safe lifting’ techniques.

Finally, poor usability of risk management information and methods is arguably an additional reason for poor risk management practices, since managers’ knowledge and understanding of occupational health and safety risk management principles appears to be generally poor. In this context, it was hypothesised that to support good understanding and usability for non-expert users, risk *assessment* methods must to some degree be adapted, as many *hazard identification* checklists have already been, to more directly match the kind of work and work environments where they are intended to be applied. One of the aims of the proposed second stage of this project is to investigate this question.

The above findings confirm the importance of proceeding to Stage Two of this project, where the focus will be on the development and evaluation of WMSD risk *assessment* methods that are usable by non-experts and that addresses a full range of hazards.

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NB: The numbers in square brackets at the end of some references refer to the numbering system used for articles in Appendix A.

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APPENDIX A. OVERVIEW OF MOST RELEVANT DOCUMENTS REVIEWED

– tabulated to show, by ‘x’ symbols in applicable columns, their coverage of workplace causal factors, risk assessment methods, and/or particular risk control issues.

Reference number	**Workplace Causal Factors**	Tools, equipment, workstation	Work organisation, job design	Environment	Individual	Mechanisms	**Risk Assessment Methods**	***Physical Hazards***	for Back MSDs	for UE MSDs	for Feet, Legs, Knees, MSDs	***Psychosocial Hazards***	Overall Job Demands	Interactions	Employee Characteristics	***wide range of hazards***	***Exposure (severity, time)***	***Effectiveness of methods***	**Risk Control**	***Control of specific types of hazard or risk factor***	Tools equip't w'station	Org'n of work, management	Job design, Personnel man'mt	Physical environment	Psychosocial Environ.	Age, gender	***WMSDs overall***	***Effectiveness/Evaluations***	**Barriers to Implementation**	Paper type L/F/R/T/M/C-G	Comments	Reference
1			Routinisation classified (5 levels)						X	x		x	x				x													F	Auto workers, Latko method; job analysis checklist	Gold, J., E., Park, J.-S., & Punnett, L. (2006
2		Tool use is part of the data collection	non-routinised work						x	x							x													F	Iron workers, Carpenters, Labourers, PATH . Discrete-interval observational sampling	Paquet, V., Punnett, L., Woskie, S., & Buchholz, B. (2000).
5										x											x	x	x		x			x		R	Stress & UEMSDs	Pransky, G., Robertson, M., M., & Moon, S., D. (2002).
7			Participatory management						x	x		x																		F	US Maines, questionnaire. Suggests that no interaction between biomechanical and work-organizational factors	Huang, G. D., Feuerstein, M., Kop, W., J., Schor, K., & Arroyo, F. (2003).
8												x																		M	Design of an interviewer-administered questionnaire	Rugulies, R., Braff, J., Frank, J. W., Aust, B., Gillen, M., Yen, I., H., Bhatia, R., Ames, G., Gordon, D., R., Janowitz, I., Oman, D., Jacobs, B., P., & Blanc, P. (2004).
9										x		x			x	x														F	Auto workers, Development of an ergonomic exposure index	Punnett, L., & van der Beek, A., J. (2000).

Reference number	**Workplace Causal Factors**	Tools, equipment, workstation	Work organisation, job design	Environment	Individual	Mechanisms	**Risk Assessment Methods**	***Physical Hazards***	for Back MSDs	for UE MSDs	for Feet, Legs, Knees, MSDs	***Psychosocial Hazards***	Overall Job Demands	Interactions	Employee Characteristics	***wide range of hazards***	***Exposure (severity, time)***	***Effectiveness of methods***	**Risk Control**	***Control of specific types of hazard or risk factor***	Tools equip't w'station	Org'n of work, management	Job design, Personnel man'mt	Physical environment	Psychosocial Environ.	Age, gender	***WMSDs overall***	***Effectiveness/Evaluations***	**Barriers to Implementation**	Paper type L/F/R/T/M/C-G	Comments	Reference
10										x		x				x										x				F	Call centre, some age data, SR quest.ionnaire, structured observation, Checklist	Norman, K., Nilsson, T., Hagberg, M., Tornqvist, E. W., & Toomingas, A. (2004).
11			"Management Standards"									x											x		x						Development of an indicator tool, SR Quest. - stress	Mackay, C. J., Cousins, R., Kelly, P. J., Lee, S., & McCaig, R. H. (2004).
12			"Management Standards"									x											x		x						Development of an indicator tool, SR Quest. – stress. 'Management Standards'	Cousins, R., Mackay, C., J., Clarke, S., D., Kelly, C., Kelly, P., J., & McCaig, R., H. (2004).
13																								x	x			x	x	F	Construction industry, Structured Interview	Van Der Molen, H. F., Sluiter, J. K., & Frings-Dresen, M. H. (2006).
15										x											x						x	x		F	Uni and Hospital, Ergonomics 'Program'; Intervention with injured workers	Bernacki, E., J., Guidera, J., A., Schaefer, J., A., Lavin, R., A., & Tsai, S., P. (1999).
16																														R	Symptom measurement instruments	Salerno, D. F., Franzblau, A., Armstrong, T., Werner, R. A., & P, B. M. (2001).
17			job rotation as a control						x								x					x						x		F	Automo bile, Modelling effectiveness of job rotation	Frazer, M., B., Norman, R. W., Wells, R. P., & Neumann, W. P. (2003).
18									X	x																				R	Posture meth. Obs'n, Direct measurement, Localised Fatigue, EMG	Li, G., & Buckle, P. (1999).

Reference number	**Workplace Causal Factors**	Tools, equipment, workstation	Work organisation, job design	Environment	Individual	Mechanisms	**Risk Assessment Methods**	***Physical Hazards***	for Back MSDs	for UE MSDs	for Feet, Legs, Knees, MSDs	***Psychosocial Hazards***	Overall Job Demands	Interactions	Employee Characteristics	***wide range of hazards***	***Exposure (severity, time)***	***Effectiveness of methods***	**Risk Control**	***Control of specific types of hazard or risk factor***	Tools equip't w'station	Org'n of work, management	Job design, Personnel man'mt	Physical environment	Psychosocial Environ.	Age, gender	***WMSDs overall***	***Effectiveness/Evaluations***	**Barriers to Implementation**	Paper type L/F/R/T/M/C-G	Comments	Reference
20										x								x												L, F	Comparison of methods, self report, Video observastion, direct measurement of Posture	Spielholz, P., Silverstein, B., Morgan, M., Checkoway, H., & Kaufman, J. (2001).
21										x		x		x																F	Blue-collar/White collar, Covariation of Physical and Psychosocial stressors; q'aire and accelerometry	MacDonald, L. A., Karasek, R. A., Punnett, L., & Scharf, T. (2001).
22									x	x											x						x	x	x	F	Various, Participative program, ManTRA	Straker, L., Burgess-Limerick, R., Pollock, C., & Egeskov, R. (2004).
23								x				x	x																	F	Various, SR Questionnaire Video	Andersen, J. H., Kaergaard, A., Mikkelsen, S., Jensen, U. F., Frost, P., Bonde, J. P., Fallentin, N., & Thomsen, J. F. (2003).
24			repetition strongest factor							x																				L	Hammering task, Factors manipulated	Crumpton-Young, L., L., Killough, K., M., Parker, P., L., & Brandon, K., M. (2000).
26						x																								R	Tabulation of risk factors and hypothesised mechanisms	Zakaria, D., Robertson, J., MacDermid, J., Hartford, K., & Koval, J. (2002).
27												x	x																	R	neck pain risk factors	Ariens, G., A. M., van Mechelen, W., Bongers, P. M., Bouter, L., M, & van der Wal, G. (2001).
28										x		x																		F	Auto workers, JCQ, Borg, Questionnaire. One year follow-up	Punnett, L., Gold, J., E., Katz, J., N., Gore, R., & Wegman, D. H. (2004).

Reference number	**Workplace Causal Factors**	Tools, equipment, workstation	Work organisation, job design	Environment	Individual	Mechanisms	**Risk Assessment Methods**	***Physical Hazards***	for Back MSDs	for UE MSDs	for Feet, Legs, Knees, MSDs	***Psychosocial Hazards***	Overall Job Demands	Interactions	Employee Characteristics	***wide range of hazards***	***Exposure (severity, time)***	***Effectiveness of methods***	**Risk Control**	***Control of specific types of hazard or risk factor***	Tools equip't w'station	Org'n of work, management	Job design, Personnel man'mt	Physical environment	Psychosocial Environ.	Age, gender	***WMSDs overall***	***Effectiveness/Evaluations***	**Barriers to Implementation**	Paper type L/F/R/T/M/C-G	Comments	Reference
29								x				x																		F	Large UK company, GHQ, PAWQ, PMI, Attribution Q, Nordic	Bartys, S., Burton, K., & Main, C. (2005).
30					Gende r																					x				R	Gender	Treaster, D. E., & Burr, D. (2004).
31								x									x													F	Auto; exposure-response score, Interviewer administered quest.; Ergonomic assessment (described)	Punnett, L. (1998).
32						x		x													x	x						x		R	Review – relies heavily on Bernard (1997)	Buckle, P., & Devereux, J. (2002).
33			x									x																		M	NIOSH Quality of Worklife Quest	National Institute for Occupational Safety and Health.
35									x																			x		M	Warehouse, NIOSH LE, 3D ssPP, LMM, Borg	Marklin, R. W., & Wilzbacher, J., R. (1999).
36		heavy workload, sedentary work	low influence, poor social relations and overtime					x				x	x		x															F	Various, Structured Interview; 24 year follow up	Thorbjornsson, C. B., Alfredsson, L., Fredriksson, K., Michelsen, H., Punnett, L., Vingard, E., Torgen, M., & Kilbom, A. (2000)
40			Duration of employment														x									x				F	Female, Symptom report	Ohlsson, K., Attewell, R., & Skerfving, S. (1989).

Reference number	**Workplace Causal Factors**	Tools, equipment, workstation	Work organisation, job design	Environment	Individual	Mechanisms	**Risk Assessment Methods**	***Physical Hazards***	for Back MSDs	for UE MSDs	for Feet, Legs, Knees, MSDs	***Psychosocial Hazards***	Overall Job Demands	Interactions	Employee Characteristics	***wide range of hazards***	***Exposure (severity, time)***	***Effectiveness of methods***	**Risk Control**	***Control of specific types of hazard or risk factor***	Tools equip't w'station	Org'n of work, management	Job design, Personnel man'mt	Physical environment	Psychosocial Environ.	Age, gender	***WMSDs overall***	***Effectiveness/Evaluations***	**Barriers to Implementation**	Paper type L/F/R/T/M/C-G	Comments	Reference
41									x																					M	Force and frequency limits	Wick, J., L. (1994).
43																														M	Symptom survey; Variant on BPD	Kristjuhan, U. (1994).
44							x											x												F, L	SA Fire Brigade, Risk ID C/L evaluation	Boucaut, B., Gun, R., & Ryan, P. (1994).
45																														M	Symptom survey; Variant on BPD	Marley, R., J., & Kumar, N. (1994).
46																														T	Conceptual Models	Huang, G. D., Feuerstein, M., & Sauter, S., L. (2002).
47						x						x																		F, T	Various - MUSIC study, Endocrine and Immune measures	Theorell, T., Haselhorn, H.-M., & Group, M. N. S. (2002).
48										x		x																		F	Service workers, EMG, questionnaires; neck pain and low biomechanical load	Holte, K. A., & Westgaard, R., H. (2002).
49																														R	Summary paper; Stress and UE MSDs	Feuerstein, M. (2002).
52			x	x								x																		F	NZ Govt Department, frequency duration demand: work stressors	Dewe, P (1991)
54								x				x	x		x		x													M	also sympotom survey, Dutch MQ	Dutch Musculoskeletal Questionnaire DMQ (2001).

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55												x										x	x		x					M	EEF WOAQ	EEF. The manufacturers' organisation (2004).
57																															Psychophysical and EMG correlates of force exertion in manual work.	Grant, K., A, Habes, D., J, & Putz-Anderson, V. (1994).
58								x				x						x									x		x	R ;T	low level biomecanical and psychosocial, advocates subjective report, surveillance	Westgaard, R. H. (2000)
60a																															Symposium of papers, OCRA, Obs methods, direct mmt; many measures reviewed	Grieco, A (2000)..
60b			Duration, repetition																												Symposium of papers, OCRA, Obs methods, direct mmt; many measures reviewed	Occhipinti, E., and Colombini, D. (2000).
60c			Duration, repetition																												Symposium of papers, OCRA, Obs methods, direct mmt; many measures reviewed	Colombini, D., Occhipinti, E., and Baracco, A. (2000).
60d										x																				M ,L	Symposium of papers, OCRA, Obs methods, direct mmt; many measures reviewed	Burt, S., Wigmore, D., Habes, D., MacDonald, L., Estill, C., Piacitelli, L., Waters, T., Baron, S., Bernard, B., and Fine, L. (2000).

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61										x							x													M	IEA/European consensus doc, based on OCRA	Colombini, D., Occhipinti, E., Delleman, N., Fallentin, N., Kilbom, A., & Grieco, A. (2001).
62			Duration, repetition							x							x													M	Strain Index	Moore, S., J, & Garg, A. (1995).
64										x							?	?												M	Latko method. ,Observation method for repetition	Latko, W.A., Armstrong, T., Foulke, J., Herrin, G., Rabourn, R., & Ulin, S. (1997).
65										x																				M	OCRA,	Colombini, D. (1998).
70																						x						x		F	Meat processing, Rest breaks	Dababneh, A. J, Swanson, N., & Shell, R.L. (2001).
71			Rest breaks																			x						x		F	Computer operators, Rest breaks	Henning, R. A., Jacques, P., Kissel, G. V., Sullican, A. B., & Alteras-Webb, S. M.(1997.
77				x								x	x																	F	Retail Handlers, Interviewer administered quest. JCQ, NIOSH Generic, other	Johnston, L.M., Landsittel, D.P., Nelson, N.A., Gardner, L, L., & Wassell, J. T., (2003).
81			strong evidence for low decision lattitude									x																		R	Psychosocial factors and LBP	Hoogendoorn, W., E., van Poppel, M., N. M., Bongers, P. M., Koes, B., W., & Bouter, L., M. (2000).
82					x				x			x					x													F	Auto workers, Interview, Workplace measurements	Kerr, M. S., Frank, J. W., Shannon, H. S., Norman, R. W., Wells, R. P., Neumann, W. P., & Bombardier, C. (2001).

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84			Work organisational factors					x				x									x	x	x		x		x		x	F	Case study, Action Research, Wide range of methods	Haims, M., C, & Carayon, P. (1998).
87	x					x		x				x	x	x					x									x		R	osha.eu,	Buckle, P., & Devereux, J. (1999).
89								x					x																	M	OWL, development and validity study	Jung, H., S., & Jung, H.-S. (2001).
90												x																		F	Netherlands, longitudinal, JCQ and others; LBP	Hoogendoorn, W., E., Bongers, P. M., de Vet, H., C. W., Houtman, I., L. D., Ariens, G., A. M., van Mcehelen, W., & Bouter, L., M. (2001).
91		Work actions	Low control, rest breaks		x					x		x			x															F	Repetitive work, quest. Medical exam.	Leclerc, A., Landre, M.-F., Chastang, J.-F., Niedhammer, I., & Roquelaure, Y. (2001).
93								x																						F	Garage workers, OWAS	Kant, I., Notermans, J. H., & Borm, P. J. (1990).
94								x																						M	HR, Edholm, OWAS, RPE	Louhevaara, V. (1995).
95								x																						F	Ambos, OWAS, Work and Health Q	Doormaal, M. T., Driessen, A. P., Landeweerd, J. A., & Drost, M. R. (1995).

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96								x																						F	Nurses, OWAS, 3D SSPP	Lee, Y., H., & Chiou, W. K. (1995).
97								x																						F	Nurses, OWAS	Engels, J. L., Landeweerd, J. A., & Kant, Y. (1994)
98								x																						F	Operating room staff, OWAS	Kant, I. J., de Jong, L. C., van Rijssen-Moll, M., & Brom, P. J. (1992
99								x																						F	Female biomedical scientisis, RULA, BPD, Nordic	Kilroy, N., & Dockrell, S. (2000).
101								x																						M	Compares subjective, observational, direct mmt of posture. "subjective methods give only limited insight."	van der Beek, A., J., & Frings-Dresen, M. H. (1998).
102								x																						R	Need for exposure-response data in order to set quantitative guides	Winkel, J., & Mathiassen, S. E. (1994).
103								x																						R	Advocates more quantitative measurement of physical load	Burdorf, A., & van der Beek, A., J. (1999).
104								x																						R	Advocates exposure measurement-intensity, freq., duration	Burdorf, A., Rossignol, M., Fathallah, F. A., Snook, S. H., & Herrick, R. F. (1997).
106		x						x																						R	Various exposure mmts	Kilbom, A. (1994)

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107			recovery periods, work duration, incentives							x							x													M	OCRA	Occhipinti, E. (1998).
110		Hand tools						x													x	x	x	x			x	x	x	F	Apparel mfg., Ergonomics 'Program'	Drury, C., G., Broderick, R., L., Weidmans, C., H., & Reynolds Mozrall, J., L. (1999).
111								x																						L	Reliability of Obs. Methods	Genaidy, A. M., Simmons, R. J., Guo, L., & Hidalgo, J. A. (1993
112								x																						L	Reliability of RPE. Methods	Wangenheim, M., Carlsoo, S., Nordgren, B., & Linroth, K. (1986). Perception
113								x																						L	VDT, Posture, Discomfort and performance	Liao, M. H., & Drury, C., G. (2000).
114																														R	Advocates ergonomic interventions, surveillance	Kilbom, S., Armstrong, T., Buckle, P., Fine, L., Hagberg, M., Haring-Sweeney, M., Martin, B., Punnett, L., Silverstein, B., Sjogaard, G., Theorell, T., & Viikara-Juntura, E. (1996).
115								x				x																		F	Tests the reliability of retrospective data	Koster, M., Alfredsson, L., Michelsen, H., Vingard, E., & Kilbom, A. (1999).

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116			low decision latitude, low social support					x				x																		F	Aluminium smelter, Structured Interview, SR Quest. , Obs Job Analysis	Hughes, R. E., Silverstein, B., & Evanoff, B. A. (1997
117		Computer interface design	Work – rest schedule					x																						L	Computer operators, Interface and Rest breaks manipulated. Effects of cognitive task characteristics.	Karwowski, W., Eberts, R., Salvendy, G., & Noland, S. (1994).
118								x																						L	Male subjects, Subjects overestimate local fatigue	Kilbom, A., Gamberale, F., Persson, J., & Annawall, G. (1983).
119								?																						L	Possible bias in rating behaviour not supported	Toomingas, A., Alfredsson, L., & Kilbom, A. (1997).
120												x																		M	Retrospective collection of psychosocial data	Thorbjornsson, C. B., Michelsen, H., & Kilbom, A. (1999
121								x																						M	Validity of self-report of postures	Mortimer, M., Hjelm, E. W., Wiktorin, C., Pernold, G., Kilbom, A., & Vingard, E. (1999).
122								x				x																		F	Retrospective collection of psychosocial and physical data	Thorbjornsson CB, Alfredsson L, Fredriksson K, Michelsen H, Punnett L, Vingard E, Torgen M, Kilbom A. (2000)

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123			Repetition							x		x																		F	Retrospective collection of psychosocial and physical data. Combinations of factors much stronger thanb individual factors	Fredriksson, K., Alfredsson, L., Thorbjornsson, C. B., Punnett, L., Toomingas, A., Torgen, M., & Kilbom, A. (2000).
124									x			x																		F	General population, Quest. & Interview	Vingard, E., Alfredsson, L., Hagberg, M., Kilbom, A., Theorell, T., Waldenstrom, K., Hjelm, E. W., Wiktorin, C., & Hogstedt, C. (2000).
125			repetitive work		x					x		x	x		x															F	Blue-collar workers, Phys-video obs; Psych-JCQ; Symptom surv	Andersen, J. H., Kaergaard, A., Frost, P., Thomsen, J. F., Bonde, J. P., Fallentin, N., Borg, V., & Mikkelsen, S. (2002).
128			repetition					x																						F	Various, SR Quest "involvement of other unmeasured factors"	Guo, H.-R. (2002).
129		Patient handling,								x		x			x															F	Nurses, Neck/shoulder, SR Quest, incl some Whitehall and NMQ	Smedley, J., Inskip, H., Trevelyan, F., Buckle, P., Cooper, C., & Coggon, D. (2003).
130												x																		F	Various - Sweden, Karasek/ Obs/ GHQ-12. Copares psychologically distressed SS with well ss.	Waldenstrom, K., Lundberg, I., Waldenstrom, M., & Harenstam, A. (2003).

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131		Repetitive tool use, arms above shoulder	Low control							x		x														x				F	Various, SR Quest, longitud. "depressive symptoms" + other predictors. Predictors differed between M & F	Leclerc, A., Chastang, J.-F., Niedhammer, I., Landre, M.-F., & Roquelaure, Y. (2004).
132												x																		R	Job stress; Non-job Stress	Bongers, P. M., Kremer, A., M., & Laak, J. T., (2002).
133												x																		R	Model presenting evidence for altered CNS function	Clauw, D., J., & Williams, D., A. (2002).
136										x																				F	Various, Denmark, Physical exposures, observation. Shoulder tendinitis	Frost, P., Bonde, J. P., Mikkelsen, S., Andersen, J. H., Fallentin, N., Kaergaard, A., & Thomsen, J. F. (2002).
137		materials handling	production speed						X	x																				F	Fishing, US, Physical exposures, observation, OWAS	Fulmer, S., & Buchholz, B. (2002).
139		keyboard										x																		F	keyboard operators, Test-retest reliability - symptom survey, JCQ, Perceived stress	Salerno, D. F., Copley-Merriman, C., Taylor, T. N., Shinogle, J., & Schulz, R. M. (2002).
140																															Computer-based survey – engineering graduate students	Schlossberg, E. B., Morrow, S., Llosa, A. E., Mamary, E., Dietrich, P. & Rempel, D. M. (2004).
141									x	x		x																		F	Canadian National Population Health Survey, modified JCQ	Cole, D. C., Ibrahim, S. A., & Shannon, H. S. (2005

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142 (see 24)																																Crumpton-Young, L., L., Killough, K., M., Parker, P., L., & Brandon, K., M. (2000).
145										x																				M	Food processing, Paper mill, Reliability and comparison of methods	Ketola, R., Toivonen, R., & Vilkari-Juntura, E. (2001).
146										x																				M	Reliability and comparison of observational methods with goniometry	Lowe, B. (2004).
147										x							x						x					x		F	Job Rotation, Job enlargement, EMG, inclinometry	Moller, T., Mathiassen, S. E., Franzon, H., & Kihlberg, S. (2004).
148										x							x													F	Turkey Processing, Job strain index, Predictive validity	Knox, K., & Moore, S., J. (2001).
150										x		x			x															F	Medical practice, Role of Individual psychological factors; Opposes terms RSI, CTD	Macfarlane, GJ, Hunt IM, Silman, AJ (2000)
151a										x											x		x					x		R	Dental hygienists, ergonomic assessment and intervention plan	Michalak-Turcotte, C. (2000).

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151b																															MSDs in Dental Hygienists	Morse, T., F, Michalak-Turcotte, C., Atwood-Sanders, M., Warren, N., Peterson, D., R., Bruneau, H., & Cherniack, M. (2003).
152			cycle time, duty cycle							x							x													L	Screw running, Psychophysical deternination of torque, cycle time and duty cycle manipulated	Moore, A., & Wells, R. (2005).
153		duration of keyboard use			x					x							x									x				F	keyboard operators, Duration of keyboard use Questionnaire	Palmer, K. T., Cooper, C., Walker-Bone, K., Syddall, H., & Coggon, D. (2001).
158										x																				F	Industrial workers, Compares observational and Accelerometry	Estill, C. F., MacDonald, L. A., Thurman, W. B., & Petersen, M. R. (2000).
159		Computer screen reflections	High quantitative job demands, low possibility for development, repetition							limited		x			x		?													F	Computer operators, SR Questionnaire. Separate logistic regressions for physical, psychosocial and individual factors.	Jensen, C., Ryhold, C., U, Burr, H., Villadsen, E., & Christensen, H. (2002).
160																					x	x	x	x			x	x		F	Newspaper workplaces, Framework for evaluation	Cole, D. C., Wells, R. P., & Group, T. W. U. E. R. (2002).

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161				X hot and vibration, jarring				x													x			x				x		F	Miners, Outlines assessment and control process;emphasis on controls	Steiner, L., Bauer, E., Cook, A., Cornelius, K., Gallagher, S., Rethi, L., Rossi, E. W., Turin, F., & Wiehagen, W. (2004).
162										x				x	x		x													F	Fish processing, Continuous exposure monitoring	Babski-Reeves, K. & Crumpton-Young, L. (2003).
163					x					x		x									x			x	x			x		F	World Bank, Stress management had no additional effect over 'Ergo' intervention	Feuerstein, M., Nicholas, R. A., Huang, G. D., Dimberg, L., Ali, D., & Rogers, H. (2004). Job
164																			x										x	F	Ergonomics consultants, Consultancy process; Barriers to Implementation; Evaluation	Whysall, Z. J., Haslam, R. A., & Haslam, C. (2004).
165		patient and equipment							x																					M	Patient handling, Risk assessment tool. Validation. 8 items with 3 levels each	Cremilde, A. T., Radovanovic, N. M., & Alexandre, C. (2004).
166									x												x							x		F	Construction labourers, LMM; participatory intervention	Hess, J. A., Hecker, S., Weinstein, M., & Lunger M (2004).
167										x		x																		M	Development of HSE ULD risk filter and assessment	Graves, R. J., Way, K., Riley, D., Lawton, C. & Morris, L. (2004).

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168									x	x					x											x				F	metal workers, SA Quest; Struct IV; Obs	Dahlberg, R., Karlqvist, L., Bildt, C., & Nykvist, K. (2004).
169									x		x										x							x		F	Carpet menders, RULA .NMQ, Increased comfort after intervention (new workstation)	Choobineh, A., Tosian, R., Alhami, Z., & Davarzanie, M. (2004).
170		characteri stics of patient, lift, lifting aid etc.							x																					M	Patient transfer, Observation method development	Warming, S., Juul-Kristensen, B., Ebbehoj, N. E., & Schibye, B. (2004).
172								?	?	?	?	?	?	?	?															M	OH Audit tool	Shelmerdine, L., & Williams, N. (2003).
173												x											x		x					C - G	NZ Guidance, leans toward Cotton & Hart	Walls, C., & Darby, F. (2004).
174												x																		F	Blue collar & White collar, demand-control-support, JCQ	De Lange, A., H., Taris, T., W., Kompier, M., A. J., Houtman, I., L. D., & Bongers, P. M. (2004).
175																					x	x	x			x		x		F	Sign language interpreters, multiple interventions	Feuerstein, M., Marshall, L., Shaw, W., S, & Burrell, L., M. (2000).

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176(see161)								?																				x			Mining, NMQ, Incident data; Intervention study with participation	Steiner, L., Bauer, E., Cook, A., Cornelius, K., Gallagher, S., Rethi, L., Rossi, E. W., Turin, F., & Wiehagen, W. (2004).
177								x													x								x	F	Brewery, Ergonomics program - cost-benefit; participation	Butler, M (2003)
178								x																						M	Methods, Review	Kilbom, A. (1994).
179										x																				M	Computer operators, Comparison self Rep/Work Samp/Activity Monitoring; SR Overestimates	Homan, M.M., Armstrong, T.J. (2003)
180(see101)								x																						M	Comparison, expert/SR/Obs/Direct	van der Beek, A., J., & Frings-Dresen, M. H. (1998).
181								x																						M	Comparison, Work diaries vs. Telephone interviews	Kallio, M., Viikari-Juntura, E., Hakkanen, M., Takala, E-P (2000)
182								x													x										Participatory approaches; IDCs	Zalk, D.M. (2001)

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188		duration of computer use								x							x	x												F	Computer operators, Comparison self Report asnd Activity Monitoring	Heinrich, J., Blatter, B. M., & Bongers, P. M. (2004).
189								x													x	x						x		R	Guidelines, Musculoskeletal load guidelines	Westgaard, R., H., & Winkel, J. (1996).
190								x																						M	Construction labourers, PATH	Buchholz, B., Paquet, V., Punnett, L., Lee, D., & Moir, S. (1996).
191				x				x				x				x														M	General application, PLIBEL. Validity and reliability	Kemmlert, K. (1995).
192								x																						M	Labour inspectorate studies, PLIBEL	Kemmlert, K. (1996).
193		extensive	extensive	x	x			x				x																		F	11 industry sectors, Q'aire developped from other studies. Stress and MSDs	Health & Safety Executive (2004).
194								x				x																		M	Tool development and testing, QEC	Health & Safety Executive (1999).
195								x				x					x													M	Tool , WERC Demand scales	Macdonald, W & Evans, O (unpublished).
196								?				?																		M	Tool- Fatigue, SOFI	Ahsberg, E. (1998).

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197												x																		M ,F	Psychosoc. and OHS, SSOS and BHCI	Burton, J., Shain, M., & Szlapetis, I. (2005)
199								x																						M	ManTRA	Burgess-Limerick, R., Straker, L., Pollock, C., & Egeskov R.
198												x																		M	Mental Health Action Checklist	Kawakami, N and Kogi, K. (2005)
200												x																		M	Wornout scale	Cox, T., & Griffith, A. (1995).
201								x																						M	Washington, Caution zone checklist	Washington. Department of Labor and Industries.
202								x																						M	Auto workers, OPEL Bochum	OPEL.
203												x																		M	COPSOQ	Kristensen, T. S., & Borg, V.
205									x	x																				M	Rapid entire body assessment (REBA).	Hignett, S., & McAtamney, L. (2000).
206									x																					M	Liberty Mutual (Snook) tables	Snook, S. H., & Ciriello, V. M. (1991).
207									x																					M	Niosh Lifting Equation	Walters, T. R., Putz-Anderson, V., Garg, A. & Fine, L. J. (1993)

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210																											X			M	Body Part discomfort	Corlett EN, and Bishop RP. (1976)
211																											x			M	Nordic Musculoskeletal Questionnaires	Kuorinka, I., Jonsson, B., Kilbom, A., Vinterberg, H., Biering-Sorenson, F., Andersson, G., Jorgensen, K. (1987)
212										x																				M	ACGIH TLV for Hand Activity (HAL)	ACGIH
401								x							x						x		?							C - G	Aus WA, Checklists	Commission for Occupational Safety and Health (W.A.), (no date)
402								x													x		?							C - G	Aus Qld, Recording forms with explanation	Queensland Workplace Health & Safety, (2000)
403		x	x	x				x				x	?								x	x		x						C - G	NOHSC Draft code 2005, Checklists	National Occupational Health & Safety Commission, (2005a)
404		x	x	x				x					?				?				x	x	x	x						C - G	NOHSC OOS CoP 1994, Checklists	National Occupational Health & Safety Commission, (1994)
405		x	x	x				x					?								x	x	x	x						C - G	NOHSC MH CoP 199o, Checklists	National Occupational Health & Safety Commission, (1990b)

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406																														C - G	NOHSC MH Std 1990, Nothing	National Occupational Health & Safety Commission, (1990a)
407		x	x	x				x					?								x	x		x						C - G	SA CoP MH (same as NOHSC 1990?), Series of questions	WorkCover Corporation (S.A.), (1990)
408		x	x	x				x					?								x	x	x	x						C - G	Vic CoP MH 2000, Checklists and worksheets	Worksafe Victoria, (2000b)
409																					x	x	x	x						C - G	NOHSC MFR Ind, Industry-specific advice	National Occupational Health & Safety Commission, (1996)
410																					x									C - G	VWA Order Picking, industry-specific advice, workplace and equipt only.rate is mentionned	Worksafe Victoria, (2004)
411																					x	x	x	x	x					C - G	Qld CoP Call Centres, very general, but clear recognition of work-organisation and related issues	Queensland Government, (2001)
413																					x	x	x	x	x					C - G	Vic ASU Call Centres, Clear explicit advice- extensive stuff on work organisation issues	Australian Services Union, (no date)

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414		x																			x	x	x	x	x					C - G	WA CoP Call Centres, Extensive, relevant advice	Commission for Occupational Safety and Health (W.A.), (2005)
415		x																			x	x	x	x	x					C - G	Comcare Guide Call Centres, More concise than other guides, CoPs. Less digestible	Comcare, (2005).
416		x	x	x					x	x				x	x						x	x	x	x						C - G	Qld Handling people, Checklists; many control examples	Queensland Workplace Health & Safety, (2001)
417		x							x												x	x		x						C - G	VWA Transferring People Safely, Assessment tools, Traffic light approach	Worksafe Victoria, (2002)
418																					x									C - G	VWA MH in Food industry, Specific controls	Worksafe Victoria, (2006)
419								x													x	x								C - G	SA Meat Industry Audit Guide, Check list, ratings	WorkCover Corporation (S.A.) (no date)
420								x					?								x	?								C - G	NZ MH CoP, Checklist with scoring	Department of Labour (NZ). (2001)
421								x					x								x	x		x						C - G	NZ VDU CoP, Mostly about controls, partic workstation and equipment	Department of Labour (NZ). (1995)
422								x													x	x		x			x			C - G	NZ OOS Guidelines, Symptom survey, and checklists	Department of Labour (NZ). (1991b)

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423								x													x	x		x	x		x			C-G	NZ OOS Guidelines for meat etc., Symptom survey, and checklists, industry specific advice	Department of Labour (NZ). (1997)
424		x	x	x																	x	x								C-G	NZ Back in Care, Virtually no Assessment	Department of Labour (NZ). (1993)
425																					x									C-G	NZ MH in the Manufacturing Industry, Control suggestions	Department of Labour (NZ). (1991a)
426									x						x						x									C-G	NZ Back in Care, Checklist	Department of Labour (NZ). (no date)
427									x	x	x	x									x	x	x	x	x					C-G	NZ Pocket Ergonomist Industrial, Symptom/Cause/action format	Department of Labour (NZ). (1986)
428									x	x	x	x									x	x	x	x	x					C-G	NZ Pocket Ergonomist Keyboard, Symptom/Cause/action format	Department of Labour (NZ). (1988
430									x												x									C-G	Sp Tech Guide MH, Variant on NIOSH LE; Many control suggestions	Ministerio de Trabajo y Asuntos Sociales (Spain), (1997e)
431								x																						C-G	Sp Tech Guide Places of Work, not specifically MSDs	Ministerio de Trabajo y Asuntos Sociales (Spain), (1997d)
432									x																					C-G	Sp Regs MH, Usual suspects	Ministerio de Trabajo y Asuntos Sociales (Spain), (1997c)

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433										x			x																	C-G	Sp Regd VDU, Usual suspects	Ministerio de Trabajo y Asuntos Sociales (Spain), (1997b)
434										x		x	x				x													C-G	Sp Tech Guide VDU, Fairly extensive; Includes checklist	Ministerio de Trabajo y Asuntos Sociales (Spain), (1997a)
440		x	x	x																										R	UK HSE Report on a Workshop, Causal factors and Clinical treatment	Harrington, JM, Hancock, J, Gompertz, D, & Spurgeon, A. (1996)
441																					x	x	x	x	x					C-G	UK HSE Call Centres, Similar to Oz guides	HELA, (2005)
442																					x	x								C-G	UK HSE Working with VDUs, Lay person's brief guide; No Assessment	Health & Safety Executive, (1998)
443										x			x								x	x		x	x					C-G	UK HSE Aching arms, Small businesss guide; Assessment (Phys) at lay level	Health & Safety Executive (2003b)
445								x													x									C-G	UK HSE MH on farms, Minimal assessment, concentrates on controls	Health & Safety Executive (2000).
446									x																					C-G	UK HSE MH Assessment Charts, Uses Traffic light approach	Health & Safety Executive (2003a).
447										x		x	x								x	x	x							C-G	UK HSE ULDs in the workplace, Filter and Assessment worksheets; incl some psysoc	Health & Safety Executive (2002a).

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450		x	x	x					x	x		x									x	x	x	x	x					C-G	Swe Ergs for prevention of MSDs, Includes some Psy (decision latitude); controls oriented	Swedish National Board of Occupational Safety and Health (1998).
451								x																						C-G	Swe Call centre checklist, Includes some explanations	National Institute for Working Life (no date)
452								x																						C-G	Swe Checklist - Computer Work,	National Institute for Working Life (1997).
460		x	x						x												x	x								C-G	US Cal Back Injury Prev. in Health Care, Recording sheets, not really assessment; emphasis on solutions	Cal/OSHA (1997).
461									x	x											x									C-G	US NC Guide to Ergonomics, No asst; concentrates on controls; very general	N. C. Department of Labor (NCDOL)a,
462									x	x											x	x	x					x		C-G	US Wa Ergonomics Program Guideline, Checklists; Concentrates on program process	State of Washington Department of Labor.
463									x	x											x	x						x		F	US NIOSH Intervention study, Posture, Force, repetition etc.; NIOSH LI; HR; BPD	National Institute for Occupational Safety and Health (1996).
464									x	x											x									M	US Mich. Office Ergo Checklist, Checklist	http://www.michigan.gov.documents/CIS_WSH_CET_D103_34476_7.pdf

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465									x	x																				M	US Wa Ergonomics Rule, Compendium of methods	Washington. Department of Labor and Industries. (a)
466									x																					C-G	US KY Your back and your job, Checklist	Kentucky Occupational Safety and Health.
467																					x									C-G	US Cal Ergonomics in Action, Emphasis on controls; Work Improvement sheet	Cal/OSHA (2003).
468									x	x											x									C-G	US Cal Easy Ergonomics, Ergonomics Awareness Checklist; Concentrates on controls	Cal/OSHA (1999).
469									x	x											x									C-G	US NC Guide to MMH and Back Safety, NIOSH LE	N. C. Department of Labor (NCDOL)b,
470		x	x	x	x																									R	US NIOSH MSDs & Workplace Factors, Bernard et al.	National Institute for Occupational Safety and Health (1997).
471																					x									C-G	US OSHA Guidelines for Nursing Homes, Emphasis on solutions	Occupational Safety & Health Administration (OSHA a)
472									x	x		x									x				x					C-G	US Or Guidelines VDT, Checklist	Oregon Occupational Safety & Health Division (OR-OSHA) (2002).
480									x	x		x									x	x		x	x					C-G	AU Vic Officewise, Extensive checklist	Worksafe Victoria, (2000a)

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481									x												x	x		x						C - G	AU NOHSC Ergs/Sprain Strain/Mining, Extensive checklist	McPhee, B. (1993
482									x												x	x								C - G	AU Qld Building Industry Advisory Standard, Industry specific ID checklist - No Asst. Many controls	Queensland Workplace Health & Safety, (1999)
490									x	x																				M	ISO 11226, static working postures	ISO 11226 (2000)
491									x																					M	ISO 11228-1, manual handling; follows NIOSH LE with variable reference mass	ISO 11228-1 (2003)
492																					x	x								M	ISO 6385, work systems	ISO 6385 (2003).
500	x																														Eur OSHA, Overview of Forecast of Risks	