A hierarchy of risk control measures for prevention of work-related musculoskeletal disorders (WMSDs)

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ABSTRACT

The conventional ‘hierarchy of control’ has been developed for use in prioritising risk control measures to achieve maximum effectiveness, but when applied to the prevention of MSDs, such an approach is too narrowly focused to be optimal. In particular, it does not support the identification and control of psychosocial hazards for MSDs, and it fails to distinguish between and effectively prioritise different types of behavioural control measures. As James Reason’s approach to safety management clearly demonstrates, the behaviour of managers and designers is likely to play a critical role in risk management, because of their capacity to generate ‘latent failures’ within an organisation. It is therefore important that behaviour-based risk control measures that target managers (and other people with a high degree of influence over workplace risk levels) are differentiated from measures that target workers who have relatively little influence on risk. To address these problems, a different kind of control hierarchy is proposed, based within a macro-ergonomics model of the work system and taking account of research evidence identifying the main hazards for MSD risk. The importance of applying this hierarchy in a highly participative way is emphasised.

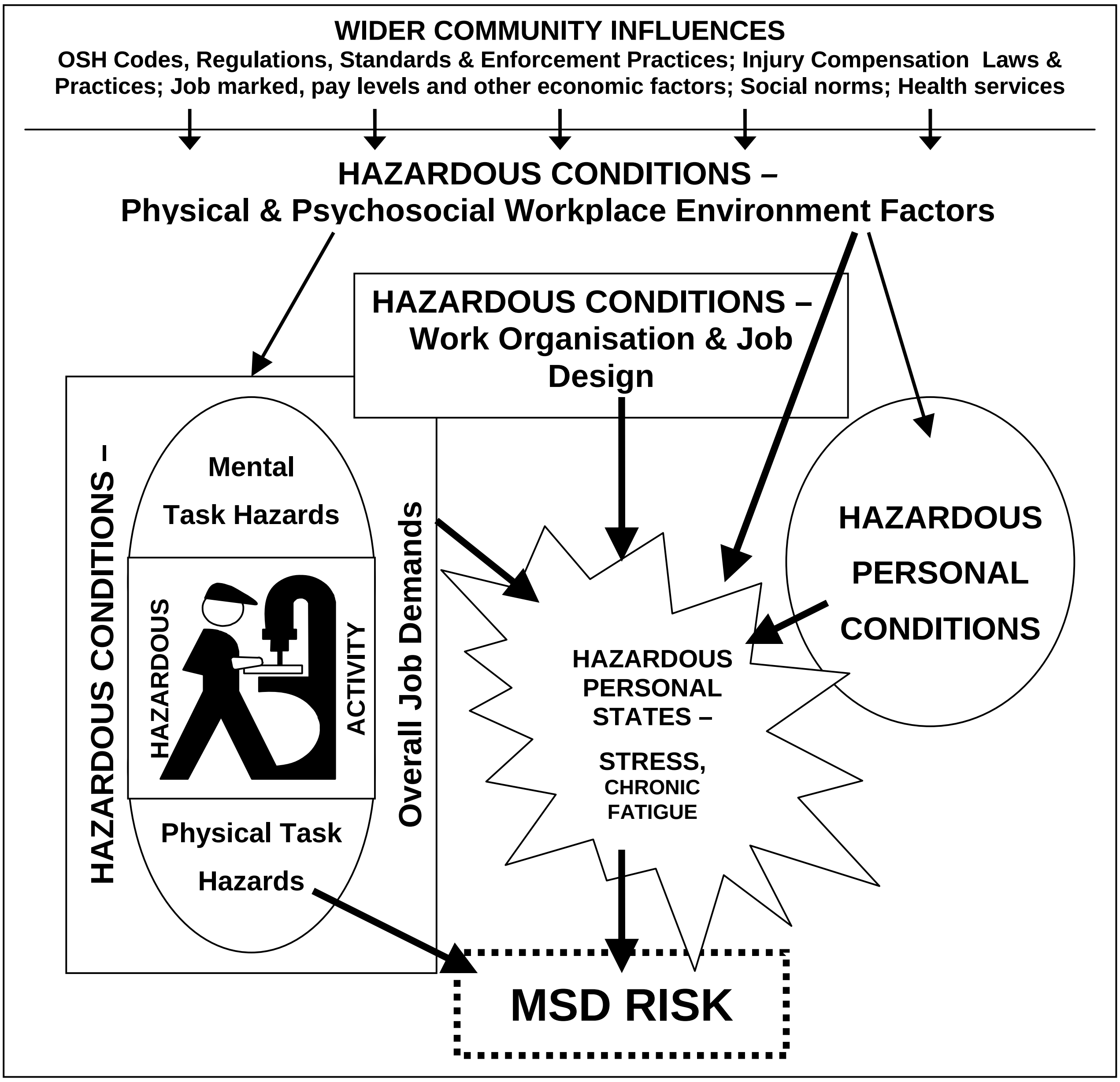
KEY WORDS: hazards, work-related musculoskeletal disorders, Occupational Safety and Health (OSH) Management Systems, hierarchy of control.

1. HAZARDS FOR MUSCULO-SKELETAL DISORDERS (MSDs)

In 2003, the International Labour Conference concluded that: “*... new strategies and solutions need to be developed and applied both for well-known hazards and risks ... as well as for emerging issues such as ... psychosocial hazards and musculo-skeletal disorders.*” (1). This paper is intended to contribute to this process, by proposing a modified form of the conventional ‘hierarchy of control’ that is more suitable for managing the risk of musculo-skeletal disorders (MSDs). These disorders include a wide range of inflammatory and degenerative conditions that are variously diagnosed as repetitive strain injuries, occupational overuse syndrome, back injury, and so on (see 2, 3). According to ILO calculations they are “the biggest single reason for economic losses” (4), which reflects the long-term nature of disabilities arising from this kind of injury. There is evidence that women suffer proportionately more than men (5), and it is likely that the extent of this problem is greatly under-reported, particularly in countries with relatively high levels of work-related fatalities.

An important barrier to reducing the risk of MSDs is the common belief that it is only (or at least, mainly) *physical* aspects of work, such as lifting and carrying heavy loads, that are hazardous. This view is reflected in most current OSH regulations and codes of practice intended to reduce MSD risk, which typically give detailed coverage of hazards related to physical task demands and only cursory, if any, coverage of other types of hazard. In fact, there is now a substantial body of evidence showing that non-physical hazards (often termed ‘psychosocial’ hazards) are also important, and that all types of hazard typically interact in their effects on risk (6, 7). Macdonald (8) categorised MSD hazards as arising from *work demands* (subdivided into physical task, psychological task, and overall job demands), *psychosocial* factors other than demands, *physical* *environment* factors, and *personal* characteristics; importantly, the effects of many of these factors on MSD risk are mediated by personal *states* of stress and fatigue. These different sources of hazard are depicted in Figure 1, which is based on a generic macro-ergonomics model of the work 'system' (9, 10). This figure represents people, varying in their coping abilities and attitudes, whose work performance entails coping with the demands of particular work tasks and with their overall jobs. How well they cope is influenced by a wide range of task-specific factors such as design of tools, equipment and workstations – some of which might expose them to physical hazards that directly increase MSD risk. Work performance tends to be fatiguing, decreasing coping capacity, and people who are concerned about the possible inadequacy of their ability to cope with demands may experience stress as a consequence, which directly increases MSD risk. The model also depicts various influences of the wider community on the work organisation, including inputs from the national OSH system, relevant legislation and enforcement strategies; in this way, the model interfaces well with the current ILO promotional framework for OSH (11).

Figure 1. Categories of work-related MSD hazards, shown within an ergonomics model of the work system.



1.1 Different types of MSD hazards

Figure 1 is well based on research evidence but, as noted above, many people have difficulty in accepting the importance of non-physical MSD hazards. To some extent, this difficulty might stem from conventional risk management terminology. Most people still think of "a hazard" as something that has a finite, physical presence, which is clearly *not* the case for some important MSD hazards. And while the formal definition of 'hazard' is now very broad, so as to encompass all types of hazard, the resultant vagueness of this definition makes it difficult to understand. To address this difficulty, the following set of more specific terms is proposed, drawing on Macdonald and colleagues (8, 12). Definitions are illustrated by examples specific to MSD risk:

Hazard: a specific object or finite event that increases risk to health in its immediate spatial or temporal vicinity; e.g. a poorly designed hand tool; an instance of threatening behaviour that may be stressful for those coping with it. (This definition is narrower than the all-encompassing ILO definition: "The inherent potential to cause injury or damage to people's health.")

Hazardous activity: an activity that *either* presents physical hazards that may directly injury the worker: e.g. heavy lifting, highly repetitive movements, prolonged static postures; *and/or* that is likely to be stressful, e.g. work that: is externally paced, highly monotonous or with short cycle times; demands a very high work rate (relative to task demands); intense concentration for prolonged periods; demands high emotional effort; errors likely to have critical consequences, etc.

Hazardous personal condition: normally experienced, sub-optimal conditions of workers that increase vulnerability to hazardous activities and conditions: e.g. pre-existing injuries; inadequate motivation to perform competently; chronic fatigue or stress states due to non-work factors such as inadequate sleep, poor diet, childcare demands, etc; low competence in performing normal work tasks, which may increase risk of hazardous errors, increase risk of stress, and increase MSD (and other) risks for others (e.g. inadequate interpersonal skills or OSH knowledge to support safe supervision or system management).

Hazardous system condition: a condition of any component of the system (equipment, workstation, work procedures and organisation, job design, management system, physical and psychosocial environments) that increases risk; e.g. very cold environment; inadequate staffing level; absent or inadequate resources (e.g. lifting aids, information, equipment, emotional support); inadequate time to complete required work; piece-rated payment system; very long working hours; badly designed shift rotation system; management system that results in workers having inadequate levels of: control or decision latitude, performance feedback, recognition/reward of effort and good performance.

Hazardous personal state: a more transient personal state, typically chronic stress or fatigue, that results from one or more of the above factors and increases risk – *directly* to that individual, e.g. due to physiological effects of the stress response, or overloading/overexertion of specific body tissues; or *indirectly* due to performance degradation and a consequent increase in errors that increase injury risk.

1.2 Hazardous activities and conditions as 'latent failures'

Examples of hazardous activities and hazardous system or personal conditions that are potentially avoidable or reducible by people's workplace decisions would be categorised within Reason's safety management model as 'latent failures' (13). The Reason model was developed to manage safety (accident risk) rather than health (including slow-onset conditions such as MSDs), but its emphasis on latent failures is analogous to the requirements for effective management of many MSD hazards. As documented by Reason and others, latent failures typically arise from poor decisions and actions of managers, and of people responsible for plant and equipment design, purchase and maintenance. Managers' and supervisors' decisions and actions can result in deficient organisational processes, poor work procedures and the routine tolerance of poor work practices, creating hazards which, over time, are likely to combine with other hazards to cause injury.

Such a framework, which directs attention to hazardous conditions and states (latent failures) as well as to directly observable hazardous activities, has the potential to be much more effective than current approaches to MSD risk management. Most approaches focus unduly on the physical activities entailed in work performance, and the usual methods of MSD hazard identification and risk assessment depend primarily on workplace inspections – a process that mainly considers directly observable factors. More effective management of cumulative injuries such as MSDs requires a broader framework that supports the identification and assessment of 'latent' hazards residing within all components and layers of the system shown in figure 1, supported by an approach to prioritising potential hazard and risk control methods that gives adequate consideration to all elements within this system.

2. A MANAGEMENT FRAMEWORK FOR MSD RISK CONTROL

Effective risk management requires identification of specific hazards, which in the case of MSDs must include the types depicted in Figure 1, including various hazardous conditions and personal states and the specific factors causing them. In contrast, the formally stated elements of an OSH management system (policy, organising, planning and implementation, evaluation, and action for improvement) are very generic, and to achieve adequate specificity it is necessary for OSH practitioners to adapt the system: "to reflect the specific conditions and needs of *organizations* .. taking into consideration particularly .. types of hazards and degree of risks."(14).

To this end, the main elements of Figure 1 have been incorporated within Table 1, along with a revised hierarchy of control. Although tailored specifically for MSD risk and hazards, the broad coverage of work system, organisational and personal components makes it potentially useful in managing most types of OSH risk where there are multiple and diverse hazards. In fact, even for *apparently* single-source risks such as those of vibration-related injuries, a strong case can be made for adopting a broad, system-based approach (15). Very similar approaches are evident in the frameworks now being used for public health risk management, such as various ecological models (16), the spectrum of prevention (17), and the Haddon matrix, which was originally developed to manage road crash risk (18, 19) and has now been applied more broadly (e.g. 20). The proposed management system is discussed in more detail in the following sections.

2.1 The importance of worker participation

The framework shown in Table 1 is not intended to be prescriptive at an organisational level. It can be used as a checklist during the process of hazard identification. Following this, the risks associated with particular hazards need to be assessed, and potential control measures identified, evaluated and prioritised.[1] While this process should be informed by the hierarchy of control shown here, it should be noted that there is no specified hierarchy across the different types of hazard; that is, there is no indication of the relative importance of controlling hazardous activities and different types of hazardous conditions. Such judgements are better made by those familiar with the specific situation, remembering that 'risk' entails not only the *likelihood* of injury but its *severity* – how 'bad' the injury would be.

Comprehensive definitions of severity must encompass criteria related to the experience and values of those potentially affected, as well as medical and financial criteria. From this, it follows that the personal views of all stakeholders should be considered both when assessing risk levels, and when prioritising possible control measures. Stakeholder groups, and individuals within each group, are likely to have diverse viewpoints and values, which will be reflected in a wide range of views on the acceptability of various risks and associated countermeasures. This great diversity of

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[1] Prioritisation will be necessary except in the unlikely situation where resources are sufficient to support implementation of *all* possible controls

viewpoints and values is illustrated by many of the contributions to the recent 'risk debate' conducted on the website of the UK Health and Safety Executive. At an organisational level, participation by all stakeholders is therefore essential, to ensure that the risk management process itself is *ethically* defensible (assuming an ethical system founded on democratic values).

Apart from ethical considerations, participation is beneficial as a means of maximising the number of hazards and potential control measures that are identified, and to enhance people's degree of work-related control, which is in itself a potentially effective means of reducing work-related MSD risk, given that inadequate control is a well-documented stressor. The ILO specifies worker participation as "an essential element of the OSH management system in the organization" (14, section 3.2.1), and research has demonstrated its cost-effectiveness and broader value in OSH management (e.g. 21, 22, 23). Currently the ILO's earlier 'control banding' project is being expanded to facilitate development of a set of risk management tools to address a wider range of hazards, including psychosocial ones, and to facilitate broad participation by ensuring that these tools are suitable for use by people who have had minimal training. In recognition of its widening scope this activity is now being referred to as the development of 'toolkits' that will together constitute a 'toolbox'. It is not yet clear whether the 'ergonomics'[2] toolkit alone will provide an adequate means of managing MSD risk, or whether the 'psychosocial' toolkit will also be needed for this.

Table 1. Proposed management framework for MSD risk, incorporating a revised hierarchy of control. The examples given in this table are not intended to represent a comprehensive set of control measures.

TYPE OR SOURCE OF HAZARD	**HIERARCHY OF CONTROLS**		
	HIGHEST PRIORITY: eliminate hazards, or reduce hazard severity	**MEDIUM PRIORITY**: avoid or minimise people's hazard exposure	**LOWEST PRIORITY**: maximise people's capacity to withstand hazard exposure
Hazardous personal conditions: personal competence, motivation, capacities	Provide training and other resources to *managers,* to enhance their competence and motivation to optimise the risk management system, and conditions that enable its effective functioning.	Implement training, procedural and supervision to enhance the OSH-related competence and performance of system designers and other technical experts.	Implement training and other measures to improve everyone's safety-related behaviours and underlying capacities.
Hazardous task-specific activities, objects and events: design or set-up of specific tasks, materials, equipment, workstations	This cell is where there is greatest focus in conventional approaches to MSD risk management. Measures include design of: • work tasks and associated processes, workstations, equipment or tools to eliminate or minimise hazardous aspects of work activities • work tasks and equipment to avoid excessively high mental demands, and the consequent potential for hazardous stress levels	• Ensure that hazardous objects or potentially hazards events (e.g. violent clients) have 'guarding' or other means of isolating them.	• Promote the wearing of appropriate personal protective equipment • Train workers in specific techniques to reduce direct risk of unavoidably hazardous tasks (e.g. physical and emotional hazards for health care workers)

[2] Attaching the term 'ergonomics' to a type of hazard rather than to a broad, system-based approach is unfortunately at odds with the International Ergonomics Association's definition and account of ergonomics.

Hazardous conditions: work and job design	• Design and implement staffing policies to ensure that sufficient numbers of people are available at all times, to avoid excessive workloads, or excessively long working hours, to avoid the development of excessive levels of fatigue or stress • Ensure that work processes and procedures, job designs and management systems do not result in chronically high levels of stress or fatigue.	• Avoid excessively long working hours • Reorganise work processes and/or redesign jobs to reduce individual exposure to specific hazardous conditions.	• Ensure that total working hours, rest break regimes, and the design of shift systems provide adequate time and opportunity for people to recover from fatigue – both physical and psychological.
Hazardous conditions: physical and psychosocial **environment**	• Modify the physical environment to eliminate or reduce hazardous conditions (extreme cold; vibration; poor lighting inducing poor postures) • Promote leadership and a workplace culture that highly values safety and minimises stress	• Reorganise work processes and/or redesign jobs to reduce total exposure***** of each person to any hazardous conditions	• Ensure that people wear appropriate PPE where necessary.

2.2 A Revised Hierarchy of Risk Control Measures

To promote the most effective possible use of available resources to prevent injury, there is a generally accepted hierarchy of control measures, which places highest priority on the measures likely to be most effective. Variants of this hierarchy are often included in government legislation or guidance material such as Malaysia's Manual of Recommended Practice for assessing workplace health risks related to the use of hazardous chemicals (24). The ILO version (14, 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. However, prioritising of the intermediate measures is often confusing. For example, the terms 'organisational' controls, 'administrative' controls and 'safe work systems' are all used in the ILO hierarchy specification, but distinctions between them are unclear. And in some other versions of the hierarchy, 'engineering' controls are listed separately from 'elimination', 'isolation' and 'substitution', when in fact engineering is a probable means of achieving elimination, isolation and perhaps even substitution, for many types of hazard. Independent of such confusions, a general prioritisation of middle-order measures is in principle difficult to justify because it is likely to vary with the nature of the hazard. Also, this kind of simple priority order takes no account of the interactions that are known to exist between physical and psychosocial hazards for MSDs, and that should be considered in particular cases.

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 MSD risk, training workers to improve their lifting or 'manual handling' techniques is typically seen as a relatively quick and cheap method and therefore as highly practicable; for these reasons it is very popular, despite evidence of its general ineffectiveness as a means of reducing risk and its low ranking within any hierarchy of controls. However, in evaluating the appropriate priority for 'training' as a control measure for MSD risk, it is important to remember that managers and designers are likely to play a critical role in risk management, because of their capacity to generate hazardous conditions and states ('latent failures') within an organisation, as discussed above. The priority placed on behaviour-based risk controls should therefore vary, depending on whether the target population is managers (and other people with a high degree of influence over workplace risk levels) or the workers who are at most risk of injury, but whose influence on risk is relatively low. Training in lifting techniques is unlikely to be effective, but training in the identification of hazards and their risks, and potential control measures, is another matter altogether – particularly if the training is for managers or system designers.

The revised hierarchy of controls presented in Table 1 is intended to address the issues outlined above. Consistent with normal practice, highest priority is on *eliminating* hazards at source, or at least *reducing* their severity; the means used to achieve this (e.g. engineering, administration) will vary depending on the nature of the hazard, so are not specified within the hierarchy. The elimination of a hazard typically requires management support; therefore, a high priority is given to training of managers in risk management principles and practices, to increase the probability of their making and effectively implementing such decisions.

The low priority given to use of PPE is consistent with convention, but here the use of PPE is categorised more generally as a means of maximising people's *capacity to withstand exposure* to hazards. This lowest category therefore also includes training in 'safe lifting' techniques but does *not* include the training of managers or others responsible for creating/eliminating hazards, or increasing/decreasing hazard severity; training in these latter categories is given a higher priority. Intermediate priority is placed on measures that either eliminate or minimise people's *exposure* to hazard, such as job rotation to increase variety, and limitations on shift durations and total working hours.

3. CONCLUSION

Some may see the present proposal for a broader approach to MSD risk management as unnecessarily complex. In response, I would claim that this proposal supports the implementation of a wider than usual range of effective control measures, and that in situations where financial resources are extremely limited, some of the measures that address psychosocial hazards might be the most practicable to implement, as well as being generally very cost-effective. Further, the adoption of a broader, systems-based approach appears to be the only means by which we are likely to achieve any further substantial reductions in MSD risk in countries where physically heavy work is much less common than previously but levels of MSDs have shown no relative improvement for many years.

Finally, a recent review of international trends in occupational health research and practice (25, p.72) argued strongly for a "new generation" approach to occupational health, concluding that "Where there have been research advances, they need to be complemented by appropriate dissemination strategies and mechanisms, which take account of the local cultural context ...." I believe that the approach I am proposing here will move us in that direction, since it combines a strongly evidence-based framework with participative procedures that are an effective means of incorporating locally important issues.

ACKNOWLEDGEMENT

I am grateful to Owen Evans for his participation in many stimulating discussions on these issues.

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