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The problem with “ergonomics injuries”: What can ergonomists do?

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ABSTRACT

Effects of psychosocial hazards on risk of musculoskeletal disorders (MSDs) are often very substantial, but workplace risk management practices focus largely on biomechanical hazards, as do the risk assessment methods used by ergonomists. Translation of research evidence into more effective workplace practices demands a more holistic risk management framework that encompasses both types of hazard.

In this context, we evaluate the validity of different MSD risk assessment methods for different purposes, focusing particularly on requirements for routine workplace risk management. These include choice of fit-for-purpose assessment methods, prioritisation of hazards that are most affecting risk, and control actions as high as possible in the risk control hierarchy.

Ergonomists could facilitate more effective workplace risk management by promoting: awareness of the need for change; improvements to guidance from OHS regulators; research on MSD-related workplace management issues; and professional development programs on this topic for ergonomists and other OHS practitioners.

1. The need for change

MSDs are the largest Occupational Health and Safety (OHS) problem in many countries (De Kok et al., 2019; Oakman et al., 2019a). A recent investigation of reasons for their continuing high prevalence in Europe identified significant deficiencies in current workplace practices, including “shortcomings in risk assessment and prevention practices” and “the lack of inclusion of psychosocial risks as part of risk assessment” (p.47) (Crawford and Davis, 2020). Such conclusions are not new (Whysall et al., 2004; Wells, 2009; Macdonald and Oakman, 2015).

What can ergonomists do about this situation? We are recognised within the OHS domain as having specialist expertise in MSD risk assessment and control. MSDs are sometimes referred to as ‘ergonomics injuries’ and the biomechanical hazards affecting them are often called ‘ergonomic hazards’, defined by Wikipedia as “physical conditions that may pose risk of injury to the musculoskeletal system”. Ergonomists have developed a wide range of MSD risk assessment methods that are widely seen as ‘best practice’ by generalist OHS professionals (Pryor, 2019). In this article we argue that workplace use of these ‘ergonomics’ assessment methods needs to be carefully considered in view both of their own limitations and of identified deficiencies in current workplace risk management practices; and further, that achievement of more effective workplace management of MSD risk requires a more holistic conceptual framework.

Current workplace practices focus largely on task-specific biomechanical hazards. These are certainly a major source of risk and controlling them is important, but they are far from being the *only* risk source. Fig. 1 categorises work-related MSD hazards into three groups corresponding with those identified in a report on musculoskeletal disorders and the workplace by the USA’s National Research Council, Fig. 1.2 (National Research Council, 2001); these groups are referred to here as: biomechanical hazards, organisational factors and psychosocial context. The latter two groups together comprise psychosocial hazards, which have been defined as “… aspects of work organization, design and management … [such as] work demands, the availability of organizational support, rewards, and interpersonal relationships in the workplace” (p.1) (Leka et al., 2017). The existence of significant relationships between psychosocial hazards and MSD risk is now well established (National Research Council, 2001; Hauke et al., 2011; Eatough et al., 2012; Lang et al., 2012; Wixted et al., 2018; Tang, 2020; Graveling et al., 2021; Taibi et al., 2021).

Fig. 1 depicts pathways via which psychosocial hazards, along with other workplace and individual factors, are known to affect workers’ MSD risk. It can be seen that work-related hazards combine with individual factors to affect risk via multiple pathways. One of these pathways starts with high *internal* biomechanical loads, while another comprises the multidimensional ‘stress response’ which is activated mainly by psychosocial hazards. Fig. 1 also shows that the stress

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response is multidimensional, including physiological, psychological and behavioural dimensions. The latter two dimensions can affect MSD risk by increasing exposures to biomechanical hazards, as when psychological stress due to perceived time pressure results in workers adopting more adverse postures or higher rates of repetitive actions. It is not surprising, then, that effects of biomechanical and psychosocial hazards may interact in their effects on risk (Faucett, 2005; Marras et al., 2000; Widanarko et al., 2015).

But psychosocial hazards affect MSD risk via *multiple* stress-related pathways. In addition to effects mediated by stress-related psychological and behavioural changes that affect biomechanical hazard exposures, as identified above, the stress response's *physiological* dimension affects MSD risk more directly, in many different ways (National Research Council, 2001; Hauke et al., 2011; Roquelaure, 2018; Nilsen et al., 2007; Elfering et al., 2008; Hallman et al., 2012; Nimbarte et al., 2012; Barsotti et al., 2021; Klyne et al., 2021). Fig. 2 depicts some of these direct physiological pathways, knowledge of which is expanding with ongoing research. For example, Barsotti et al. (2021) detailed how the stress response affects "the function of the fibroblasts and myofibroblasts that reside throughout the body and more specifically in the fascia, a ubiquitous and multi-functional connective tissue", which affects various aspects of musculoskeletal functioning and related pain (Ajimsha et al., 2020; Schleip et al., 2010). A recent EU-OSHA review of evidence-based conceptual models of the relationship between psychosocial hazards and MSD risk concluded that an ideal model should depict "the important double pathway between psychosocial factors and MSDs (both directly and through affecting physical strain)" (pp. 42–43) (Graveling et al., 2021). The model in Fig. 1 is consistent with that view.

Importantly, effects of psychosocial hazards and resultant stress on MSD risk, while highly variable, are often comparable in size to those of biomechanical hazards (Widanarko et al., 2015; Marras et al., 2009; Oakman, 2014; Oakman and Chan, 2015; Neupane et al., 2017; Candan et al., 2019; Bodin et al., 2020; Dianat et al., 2020; Liu et al., 2020). For example, Marras et al. (2009) reported that the relative effects of biomechanical versus psychosocial hazards varied considerably between different studies:

> "Between 11% and 80% of low-back injuries and 11–95% of extremity injuries, are attributable to workplace physical factors, whereas, between 14% and 63% of injuries to the low back and between 28% and 84% of injuries of the upper extremity are attributable to psychosocial factors" (p.16).

Such variability is not surprising, for many reasons including the likelihood that the relative impact on risk of psychosocial versus biomechanical hazards may vary between occupational groups that differ in their hazard exposure profiles. Nurses are typically exposed to substantial levels of both biomechanical and psychosocial hazards. In a systematic review of evidence concerning risk factors for healthcare workers (mainly nurses and nursing auxiliaries), Lang et al. (2012) reported odds ratios ranging from 1.07 to 4.45 for various psychosocial hazards and from 1.74 to 2.20 for various biomechanical hazards. Calculating overall means of the odds ratios reported for each study in that review, it is found that mean values were higher for psychosocial hazards (2.21) than biomechanical hazards (1.99), which might suggest that psychosocial hazards had a greater effect on MSD risk. We see such a conclusion as unwarranted – in part because of the wide variability in hazard measurement methods and associated problems (discussed in sections 2 and 3 below). There is also evidence that the relative impact of psychosocial versus biomechanical hazards may vary according to the body site affected. A nationwide survey across a wide range of occupational groups by Liu et al. (2020) found that psychosocial hazards were stronger predictors of shoulder and neck disorders while biomechanical hazards were stronger predictors of lower back and wrist or hand disorders.

Based on all available evidence, it is clear that focusing workplace MSD risk management mainly on biomechanical hazards is unwarranted; effective management requires assessment and control of MSD risk from psychosocial hazards also. Unfortunately, current workplace MSD risk management practices largely fail to address psychosocial hazards, which limits their effectiveness (Crawford and Davis, 2020; Whysall et al., 2004; Wells, 2009; Macdonald and Oakman, 2015). In Australia, this deficiency in MSD risk management practices has been found in the following industry sectors where MSD incidence is problematic: manufacturing and warehousing (Macdonald et al., 2008); residential aged care (Oakman and Bartram, 2017); residential aged care and transport/logistics (Oakman et al., 2018, 2019b); and healthcare, retail and transport/logistics (Robertson et al., 2021).

A strong focus on biomechanical hazards is also evident in the MSD risk assessment methods used by ergonomists. Dempsey et al. (2019) surveyed 405 certified ergonomics professionals (CPEs) in six

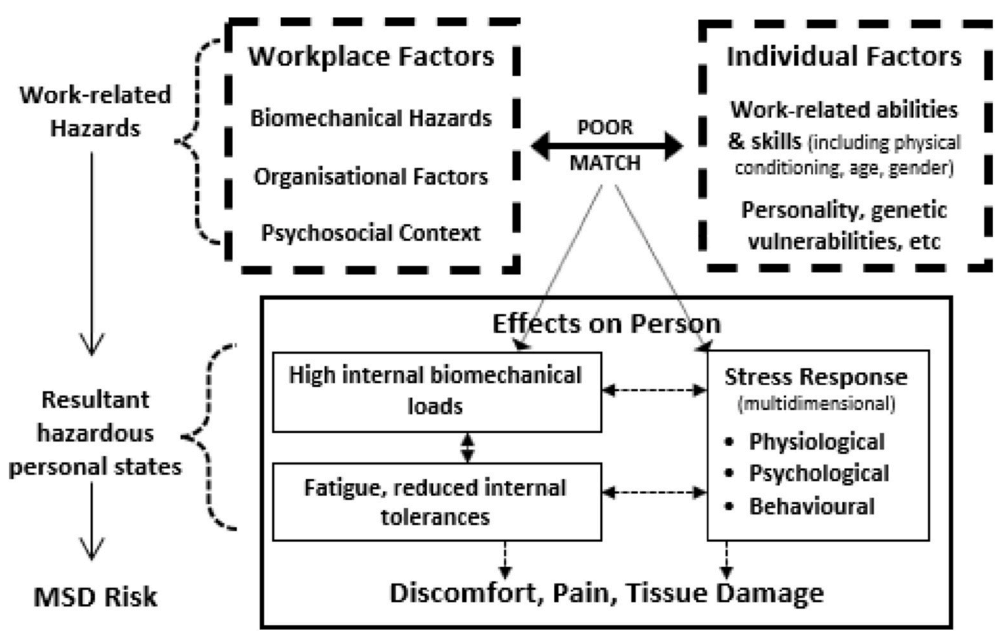

Fig. 1. Model of factors affecting MSD risk (based on model of Macdonald and Oakman, 2015).

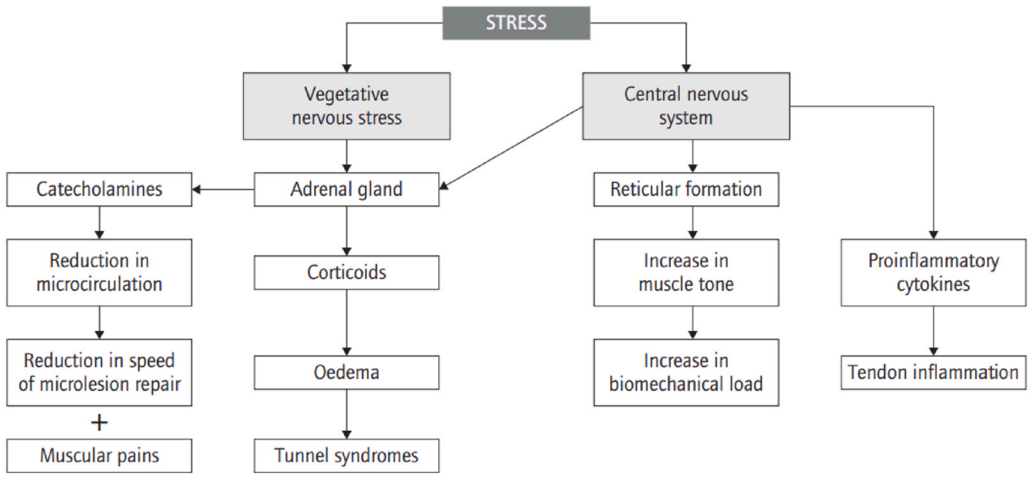

Fig. 2. Some physiological pathways via which the 'stress response' affects MSD risk (Roquelaure, 2018, based on Aptel et al., 2011).

English-speaking countries, presenting participants with a list of 17 mainly observation-based (observational) risk assessment methods. Only one of these – the Job Content Questionnaire (JCQ) – assessed risk from psychosocial hazards. Percentages reporting use of the JCQ, separately by country, were: 21% USA, 13% Canada, 30% UK/Ireland, and 34% Australia/New Zealand. Oakman et al. (2022) investigated methods used by 29 Australian OHS professionals, 9 of whom were ergonomists. Participants were shown a list of 33 methods, 8 of which focused on psychosocial hazards; only 3 of the 29 interviewees reported using any of the latter.

This biomechanical focus is longstanding: in 2004, research by Whysall et al. (2004) found that many UK ergonomics consultants saw psychosocial factors as "outside their remit". The authors commented that: "This is perhaps surprising given the notion of ergonomics as a 'holistic approach to understanding complex and interacting systems' … and the widely recognised importance of the contribution of psychosocial factors to MSDs." The continuing focus of MSD risk assessment on biomechanical hazards accords with common understandings of 'ergonomics injuries' and the 'ergonomic hazards' seen as causing them, but it conflicts with evidence of the much broader range of factors affecting MSD risk. It also sits uncomfortably with the International Ergonomics Association's (IEA) view of 'ergonomics', which they define as:

> "a multi-disciplinary, user-centric integrating science [which uses] a holistic, systems approach to apply theory, principles, and data from many relevant disciplines to the design and evaluation of tasks, jobs, products, environments, and systems. [It takes into account] physical, cognitive, sociotechnical, organizational, environmental and other relevant factors …. ". (International Ergonomics Association, 2021)

The IEA's broad view of ergonomics, together with current evidence that psychosocial hazards can substantially affect MSD risk, indicates that ergonomists should be promoting a more holistic approach to workplace MSD risk management – addressing all types of MSD hazards within a 'macro-ergonomics' systems framework. In the following sections we consider currently available methods that might be used to achieve this. We first evaluate validity of the task-specific methods typically used by ergonomics practitioners to assess MSD risk, followed by discussion of methods suitable for assessing job-level MSD risk as part of routine workplace risk management. In the final section, we suggest some implications for ergonomists.

2. Validity of observational methods of MSD risk assessment

Reliability is a prerequisite for validity. Diego-Mas et al. (2017) evaluated 442 assessments submitted by 290 users of RULA (McAtamney and Corlett, 1993), OWAS (Karhu et al., 1977), REBA (Hignett and McAtamney, 2000), NIOSH Lifting Equation (Lu et al., 2014), OCRA checklist (Colombini and Occhipinti, 2016), and a computerised biomechanical model. Thirty percent of assessments had errors, which were severe enough to completely invalidate results in 13% of assessments. The extent to which errors arose from a method's intrinsic lack of reliability versus its misapplication by practitioners is unclear, but resultant reliability was not good.

The validity of observational methods is also open to question. They are clearly unsuitable for assessing risk from psychosocial hazards because most of these hazards affect risk primarily via workers' stress responses to them. Even when only risk from biomechanical hazards is relevant, validity is evidently variable. Using procedures that maximised reliability, Chiasson et al. (2012) applied eight methods to assess 224 workstations involving 567 tasks. They found many major discrepancies between methods; for example:

> "The HAL classified 37% of the workstations as low-risk to the hand and wrist compared to JSI with 9%. … The FIOH, RULA and REBA methods did not identify any workstations as low risk. The QEC method [classified] 35% of the workstations as high risk compared to RULA with 76%. The QEC Hand/wrist and OCRA Hand/wrist/elbow indices showed similar results for the number of workstations classified as high risk, but did not classify the same workstations in this category."

Given such variability, it follows that some methods did not produce valid assessments of some tasks-workstations.

Valid assessment requires (Kimberlin and Winterstein, 2008; Takala et al., 2010; Stanton, 2016):

- *Construct validity* – assesses hazard constructs identified as important by an evidence-based theoretical model of factors affecting MSD risk
- *Content validity* – assesses risk from construct manifestations that are most relevant in the particular case; this depends on how constructs are operationalised and measured, and how well that matches the hazard configuration of the task-workstation assessed.
- *Criterion validity* – assessment results accord with those produced by other measures of known validity. This includes *concurrent* and/or *predictive* validity.

It is not difficult to select an observational method with acceptable ***construct*** validity for assessing risk from biomechanical hazards. Key constructs include workers' postures (sustained or awkward), forces exerted (high or sudden), repetitive movements, and exposure to vibration. It is much more difficult to achieve good ***content*** validity because methods vary widely in their sensitivity to differences in severity of each hazard and their coverage of different body regions. No single method provides equally good coverage of all biomechanical hazards and all body regions (Takala et al., 2010; David, 2005; Malchaire et al., 2011). It seems likely that the variation between methods in assessment outcomes found by Chiasson et al. (2012) was due, at least partly, to variation in their content validity for some of the tasks-workstations assessed.

Clearly, choice of method(s) is critically important to achieve adequate construct and content validity. It requires (a) recognition of the hazard configuration presented by a particular task-workstation, and (b) selection of one or more methods to provide adequate coverage of that configuration. Method selection therefore requires considerable knowledge of both hazard constructs and assessment methods.

To achieve ***criterion*** validity, requirements differ according to the assessment's purpose: a method can be valid for one purpose but not for another (Takala et al., 2010; David, 2005). Little is documented about the 'real world' purposes for which assessment methods are used. It seems likely that they are most commonly used to:

(1) compare MSD risk from different configurations of biomechanical hazards – as when evaluating alternative task-workstation designs, or effects of changes to the task or workstation;
(2) evaluate, in a more absolute sense, the level or acceptability of MSD risk from biomechanical hazards of a particular task-workstation.

For Purpose 1, *concurrent* validity is sufficient. This requires good correspondence between hazard levels measured by the method in question and another method of known validity such as direct measures of biomechanical loads (Marras et al., 2010) or body motion capture technology (Ranavolo et al., 2020). Takala et al. (2010) concluded that for 19 of the 30 observational methods they reviewed there was "moderate-to-good" agreement with concurrent measures derived from video-based hazard observations, but agreement with technical measurements was lower.

For Purpose 2 above, the risk assessment method requires *predictive* validity in relation to outcome measures such as musculoskeletal discomfort or pain levels, MSD diagnoses or workers' insurance claims. This is important when assessment might be used to determine the need for, or urgency of, risk control actions. There are reported cases of observational methods being predictive of MSD outcome measures (e.g. Lu et al. (2014) Klussmann et al. (2017)), but Takala et al. (2010) found such evidence was available for only 12 of the 32 methods they reviewed. Even when the method's content validity is good and there are no errors in its application, assessment based on a sample of observations of workers performing a particular task can be expected to predict the MSD risk of those workers (that is, *job*-level risk*) only* when the hazards assessed are the main ones affecting workers' risk. Often this will *not* be the case because:

- Workers typically perform multiple tasks, many of which might not be sufficiently hazardous to warrant assessment but could add to workers' overall hazard exposures
- MSD risk from psychosocial hazards is largely excluded from assessment by observational methods because most psychosocial hazards arise from wider aspects of the job, and because their assessment requires substantial input from workers.

The first of these dot points was addressed in a project by Gerr et al. (2014a) They analysed 10-min samples of all tasks comprising the job, using three different observational methods to achieve content validity. Workers were required to keep a log of time spent on each task throughout the week to enable calculation of time-weighted biomechanical exposure levels. Garg et al., (2014, 2017) used similarly rigorous strategies to calculate job-level risk from biomechanical hazards. Such procedures require considerable time and expertise so are not practicable as part of routine workplace management procedures. Use of wearable technology might present an alternative, but in many workplaces this also would be impracticable.

Gerr et al. (2014b) addressed the second dot point by surveying workers to assess MSD risk from psychosocial hazards. Reported effects of psychosocial hazards on clinically diagnosed MSDs were more often significant and had substantially larger hazard ratios than those for the biomechanical hazards affecting these workers as reported by Gerr et al. (2014a) This is consistent with the overall evidence that psychosocial hazard effect sizes are often large and sometimes larger than those of biomechanical hazards (Widanarko et al., 2015; Marras et al., 2009; Oakman, 2014; Oakman and Chan, 2015; Neupane et al., 2017; Candan et al., 2019; Bodin et al., 2020; Dianat et al., 2020; Liu et al., 2020).

In summary, task-focused methods are designed to assess MSD risk from biomechanical hazards of particular work tasks, but are not suitable for assessing *job-level* MSD risk. Workplace assessment of job-level MSD risk is discussed in the following section.

3. Workplace MSD risk assessment

3.1. OHS legal requirements of workplace managers

Workplace managers in most jurisdictions throughout the world have a legislated duty to manage *all* sources of risk to workers' health and safety. For risks such as MSDs that are affected by a large and diverse range of potentially interacting hazards, including work-related psychosocial hazards, this is particularly challenging (Macdonald and Oakman, 2015; Macdonald, 2012). According to one OHS regulatory body, management of risk from psychosocial hazards needs to be "… a continuous exercise within the organisation" because "The dynamics and complexity of organisations can mean that changes such as a new supervisor, new workers or new processes or procedures can have marked, unexpected and unplanned effects on workers" (p.6) (Workplace Health and Safety Queensland, 2019).The continuous nature of workplace risk management requirements is shown in Fig. 3.

Fig. 3. The cyclical process of occupational health risk management. (From *Code of Practice: How to manage work health and safety risks,* Safe Work Australia (Safe Work Australia, 2018a).).

Because of the large number of hazards affecting workers' MSD risk and the inevitably limited availability of risk management resources, it is usually impracticable to address risk from *all* hazards found to affect risk at any given time. Risk control actions therefore need to be prioritised to address the 'worst' hazards – those that are most affecting MSD outcomes. Prioritising such hazards promotes more cost-effective risk control and in some jurisdictions is a legal requirement. Metzler et al. (2019) pointed out that:

> "… identifying the most harmful hazards and reducing their risk is of great significance for risk management, as this is a prerequisite for complying with the [EU] framework Directive 89/391/EEC in improving safety and health of workers …. " (p.128).

In accordance with this, the UK Health and Safety Executive advised that employers should:

> "Assess the risks, identify what could cause harm in the workplace, who it could harm and how, and what you will do to manage the risk" and "*Decide what the priorities are and identify the biggest risks*" (p.8, *italics added*). (Health and Safety Executive, 2013)

3.2. Current workplace MSD risk assessment methods

The heavy focus of workplace practices on biomechanical hazards reflects guidance from OHS regulatory bodies (Safe Work Australia, 2018b; Health and Executive, 2020), which often includes hazard checklists or worksheets that provide good coverage of those but little mention of psychosocial hazards (e.g. Safe Work Australia, Appendix F (Safe Work Australia, 2018b)). And while checklists support *identification* of biomechanical hazards, they do not provide a formally structured *assessment* method. This is problematic because unstructured assessments lack reliability – even when performed by professional ergonomists experienced in MSD risk assessment (Eliasson et al., 2017). Checklists and worksheets are therefore likely to identify many biomechanical hazards but provide no reliable basis for prioritising risk controls.

Focus on task-specific biomechanical hazards is also evident in the methods used by occupational ergonomists. Dempsey et al. (2019) found that those most commonly used by ergonomists in several English-speaking countries were: RULA (McAtamney and Corlett, 1993), REBA (Hignett and McAtamney, 2000), the NIOSH Lifting Equation (Lu et al., 2014), and psychophysical material handling data. Eliasson et al. (2019) found the method most commonly used by Swedish ergonomists was one specified by the Swedish regulator, followed by Key Indicator Methods (Steinberg, 2012) and the QEC (David et al., 2008). In Australia, Oakman et al., (2022) found that PErforM (Burgess-Limerick et al., 2007) was most widely used, followed by the NIOSH Lifting Equation, Borg RPE (Williams, 2017), RULA, and REBA.

Many guidance documents refer workplace users to observational assessment methods for use in more complex situations (e.g. Safe Work Australia, Appendix G (Safe Work Australia, 2018b)). Limitations of observational methods, particularly their inadequate coverage of psychosocial hazards, are not well recognised at workplace level. In two Australian industry sectors with high MSD risk, only 11 of 65 interviewees (OHS managers, general managers, workers' health and safety representatives) knew that psychosocial hazards could affect MSD risk (Oakman et al., 2019b). Most workplace stakeholders therefore assume that observation-based assessment provides an adequate basis for selecting MSD risk control actions – particularly when assessment results are presented in action-oriented terms. For example, REBA reports risk in terms of five 'Action levels' ranging from "Negligible risk – no action needed" through to "Very high risk – implement change now" (Hignett and McAtamney, 2000); similarly, the MAC tool uses terms such as 'prompt action needed' (Health and Safety Executive, 2019). When workplace risk management resources are limited, such terminology seems counterproductive because unmeasured psychosocial hazards could be having a greater effect on MSD risk and therefore more urgently requiring control.

Whysall et al. (2004) identified a need for "Development of tools/techniques to enable holistic assessment, integrating factors relating to the organisation, worker, work tasks, work environment, and interactions between these factors" (p.350). In the following section, we outline evidence of several validated questionnaires that address this need, enabling valid assessment of *job-level* MSD risk.

3.3. Questionnaires validated for job-level MSD risk assessment

Questionnaires asking workers to rate their exposures to both biomechanical and psychosocial hazards across their overall job provide an alternative to assessment based on observations of task performance. Questionnaire ratings depend on workers' perceptions and memories of their exposures rather than on expert observations. Because of this they may lack *face* validity for workplace stakeholders who are unaware of research evidence that questionnaires with good construct, content and criterion (predictive) validity are now available for job-level MSD risk assessment, as described below.

Construct and content validity. For a questionnaire assessing *biomechanical* hazards, these forms of validity are relatively easy to ensure because such hazards are few and quite easily described. Psychosocial hazards are much more numerous, making it harder to include all that are relevant without creating a questionnaire that is too long for routine workplace use. Some psychosocial hazard questionnaires are based on a particular theoretical model, which limits the constructs addressed; others include constructs from multiple theories. Given the large number of hazards and the varying perspectives of different theories, it is unsurprisingly that none of the 17 most widely cited psychosocial hazard questionnaires provide comprehensive coverage of constructs (Kop et al., 2016). Also, there is evidence that the relative impacts on risk of some psychosocial hazards can vary between occupational groups such as blue-collar versus white-collar jobs (Oakman and Chan, 2015; Metzler and Bellingrath, 2017; Berthelsen et al., 2020).

Ensuring construct and content validity of a psychosocial hazard questionnaire requires selection of one that (a) covers the constructs that are most relevant for the particular job and workplace, and (b) represents each construct by items worded appropriately for the type of job and workers' literacy levels. As noted above, Dempsey et al. (2019) found the JCQ was most widely used by ergonomists. The Copenhagen Psychosocial Questionnaire (COPSOQ) is also widely used. It is based on multiple theoretical models so covers more hazard constructs than the JCQ, and its nomological validity (akin to construct validity) has been established in relation to the Job Demand-Resources model (Berthelsen et al., 2018).

For the present purpose, predictive validity in terms of MSD outcomes is a key requirement. Evidence of this is outlined below, separately for psychosocial and biomechanical questionnaires.

Criterion (predictive) validity of psychosocial hazard questionnaires. There are countless publications demonstrating predictive validity of psychosocial hazard questionnaires in relation to workers' stress levels, and structural equation modelling of COPSOQ data shows that stress is in turn a predictor of MSD risk (Wixted et al., 2018), as depicted in Figs. 1 and 2. Bergsten et al. (2015) demonstrated the predictive validity of COPSOQ in relation to MSD risk of 525 airport baggage handlers. Severe low back pain was predicted by the following eight COPSOQ scales: Possibilities for Development; Variation; Meaning of Work; Commitment to the Workplace; Recognition; Social Support from Colleagues; Social Support from Supervisors; and Interpersonal Relations. Using the JCQ, Gerr et al. (2014b) found that high Psychological Demands was a strong predictor of hand/arm MSDs (both symptoms and diagnosed disorders), particularly when Decision Latitude was low. Similarly, Bugajska et al. (2013) found that higher levels of Psychological Demands increased the probability of lateral and medial epicondylitis among 725 employees in the health, communications and manufacturing sectors, while higher levels of Decision Latitude decreased risk of carpal tunnel syndrome.

Less commonly used is the Work Organisation Assessment Questionnaire (WOAQ) which, like COPSOQ, assesses constructs from several theoretical models. It is of interest here because its content is designed for use in the manufacturing industry sector (Griffiths et al., 2006), so is well suited to many workplaces where MSD risk is problematic. Importantly, it has predictive validity in terms of MSD symptoms and consequent time lost from work (Oakman and Chan, 2015; Macdonald et al., 2008; Oakman and Macdonald, 2012).

Criterion validity of biomechanical hazard questionnaires. Fewer questionnaires are available for assessing risk from biomechanical hazards, presumably because observational methods are viewed as more valid. This might be true if ***concurrent*** validity in terms of technical measures of hazard levels were the key requirement – although Barrero et al. (2009) found that evidence concerning their concurrent validity was inconclusive and suggested that "commonly accepted views about the poor-to-moderate validity assessment should be reconsidered". One reason for lack of close correspondence between worker ratings of biomechanical hazards and alternative measures is that people with MSD symptoms tend to give higher rating than those without such symptoms (Balogh et al., 2004), probably because pre-existing symptoms make them more sensitive. For workplace risk management purposes, this might actually be an advantage because symptomatic people are at higher risk so arguably it is helpful if their ratings draw more attention to hazards that are most affecting them. The need to manage risk of such people is of growing importance because symptoms are more common among older people (Okunribido and Wynn, 2010), and many countries have ageing populations with people working to older ages (Fischer et al., 2021).

However, a questionnaire's ***predictive*** validity in relation to MSD symptoms or diagnosed cases is the key requirement for the present purpose since these outcomes are centrally important for workplace managers. The Dutch Musculoskeletal Questionnaire has been validated in relation to symptom levels (Candan et al., 2019; Hildebrandt et al., 2001; El-Helaly et al., 2018). Similarly, biomechanical hazard exposures assessed by the Job Factors section of the Job Requirements and Physical Demands survey were validated in relation to both symptoms and clinical outcomes (Daniels et al., 2005). A 12-item scale measuring biomechanical hazards as part of the APHIRM toolkit has also been validated in relation to symptom levels (Oakman and Macdonald, 2019; Oakman et al., 2014; Maakip et al., 2016). An earlier 3-item version of this scale was similarly validated (Oakman and Chan, 2015), and symptom scores were shown to reflect the incidence of MSD-related workers' compensation claims across different body regions (Macdonald et al., 2008). Various other project-specific surveys of a full range of biomechanical hazard exposures have been similarly validated (Liu et al., 2020; Herin et al., 2012).

In summary, validated questionnaires are available to assess job-level MSD risk from both biomechanical and psychosocial hazards, generating a hazard profile for a whole job based on workers' mean ratings for each hazard. If there are too few workers to provide reliable mean values for each hazard, it may be preferable to use a single set of hazard ratings generated by group discussion of each questionnaire item.

4. Translate results from risk assessment into effective risk control actions

Workplace risk assessment is of little value if it does not result in effective risk control. Recent European research found that many employers failed to engage with the risk prevention process and among those who did, the focus was on assessment rather than prevention (Crawford et al., 2020). These researchers recommended that "The focus on risk assessment should be changed to a focus on risk assessment and prevention activities" (p.11). Some key requirements for effective prevention activities are outlined below.

Prioritise the 'worst' hazards. Risk control actions are more likely to be effective when they target hazards that are having the greatest effect on risk, and in some jurisdictions such prioritisation is mandated (Section 3.1). To provide a good evidence base for prioritising control actions, managers need to assess hazard levels and then evaluate how much risk each hazard presents to workers' health. Drawing on conventional conceptions of 'risk', Clarke and Cooper (2004) proposed that evaluation of risk from psychosocial hazards should take account of both the mean level of each hazard (from questionnaire ratings) and its correlation with the harmful outcome of concern, which in the present case is MSD risk. Metzler et al. (2019) compared four risk evaluation methods: mean hazard ratings; deviation of mean hazard ratings from industry norms; multiple regression analysis of hazard ratings in relation to outcome measures; and the method proposed by Clarke and Cooper. Based on analysis of COPSOQ data from 549 workers in different occupations within a steel manufacturing company, they concluded that the Clarke and Cooper method was the most promising means of prioritising psychosocial hazards.

A similar method of prioritising MSD risks from both psychosocial and biomechanical hazards was developed by Oakman and Macdonald as part of the APHIRM toolkit, which is designed for workplace management of MSD risk (Oakman and Macdonald, 2019). The toolkit includes a survey that assesses MSD symptoms as well as biomechanical and psychosocial hazards (the latter mainly from COPSOQ, supplemented by WOAQ items). An online algorithm identifies the 'worst' hazards across both categories, based on correlations between hazard ratings and MSD symptom scores; highly rated biomechanical hazards are prioritised regardless of correlations. Further research on such algorithms would be helpful, but the need to take account of relationships between hazards and harmful outcomes seems clear, especially for psychosocial hazards.

Identify job-specific sources of risk. When risk assessment is based on observation of task performance, the sources of risk are clear. But when a questionnaire is used, items necessarily describe hazards in generic terms so ratings must be understood in relation to specific aspects of the particular job and workplace. For example, with biomechanical hazards this might entail identification of the particular activities generating a poor rating for 'frequent, highly repetitive actions'. Similarly for psychosocial hazards, specific causes of poor ratings of "senior management attitudes" or "people here are treated fairly" must be identified.

When a questionnaire is completed by individual workers, information about causes can be elicited using participative ergonomics procedures (Burgess-Limerick, 2018). Workers can be asked about the prioritised hazards via formal focus groups and individual online feedback (Oakman and Macdonald, 2019), or less formally via discussions at 'toolbox' meetings. Suggestions for control actions can also be obtained in these ways. If the questionnaire is completed jointly by a small group of workers, the discussion required to rate each hazard can also encompass job-specific causes and potential risk control options. Participative procedures such as these also ensure compliance with the requirement to 'consult' workers, which is mandated in Australian and some other OHS jurisdictions (Safe Work Australia, 2018c).

Implement controls as high as possible in the risk control hierarchy. The last stage of the workplace risk management cycle (Fig. 3) entails implementation of risk control actions, where a fundamental principle is that actions should be prioritised in accord with the conventional risk control hierarchy – aiming to eliminate or reduce risk at its sources rather than by instructing or training people to protect themselves. This hierarchy accords with the basic ergonomics principle of 'fitting work to the worker' rather than vice versa. OHS legislation, codes of practice and guidance promote this hierarchy. For example, it is highlighted in regulator guidance on 'Hazardous Manual Handling' (WorkSafe Victoria, 2017), supported by a statement that "… more training in policies or procedures … does not provide a higher level of protection and is likely to be ineffective". Nevertheless, workplaces continue to rely heavily on changing workers' behaviour. Training in manual handling techniques is probably the most commonly used control action in Australia and Europe (De Kok et al., 2019; Crawford and Davis, 2020; Oakman et al., 2018), despite evidence that it is usually ineffective in reducing risk (Verbeek et al., 2011; Hogan et al., 2014).

5. Conclusions: what can ergonomists do to achieve more effective MSD risk management?

Work-related MSDs are one of the most widespread and costly OHS problem throughout the world, and ergonomists are recognised experts in MSD risk assessment and control. What can – and should – ergonomists do to reduce the incidence of these 'ergonomics injuries'?

Professional ergonomists are members of a "profession that applies theory, principles, data, and methods to ***design*** in order to optimize human well-being and overall system performance" (International Ergonomics Association, 2021, italics added). The most widely used methods of MSD risk assessment are suitable for use when the purpose is ***to evaluate or improve design of a physical task, associated workstation and tools*** by eliminating or reducing risk from biomechanical hazards. This may be based on structured observations of workers performing the task in question – using workstations and equipment that is currently in use or, when these are still at the planning stage, using prototypes. Workers involved should represent the anthropometric range of actual or expected workforce users.

In this case, valid and reliable assessment requires ergonomics expertise sufficient to:

- Select one or more methods to assess all biomechanical sources of risk from that task
- Implement the method correctly
- Interpret and communicate results accurately – making clear that the diagnosed risk level relates *only* to that task's biomechanical hazards so is not a reliable indicator of workers' overall MSD risk.

But task design is very different from the design of whole ***jobs.*** Good job design demands consideration of a much broader range of factors, including psychosocial hazards and other job characteristics that may influence both work performance and wellbeing (Smith and Sainfort, 1989; Kompier, 2003; Tims et al., 2013); this cannot be achieved using just observation-based MSD risk assessment methods. Because of their typical focus on a specific task, few if any observation-based methods provide *job*-level coverage of even biomechanical hazards, unless the job comprises only one or very few tasks. For these reasons, when the purpose of risk assessment is ***to reduce MSD incidence in a particular group of workers***, a more holistic approach to risk assessment is required.

The International Ergonomics Association specifies that:

> "In order to practice effectively, human factors and ergonomics professionals who are specialists in a given domain or discipline must address issues and challenges with sufficient consideration of all of the relevant elements of HFE." (International Ergonomics Association, 2021).

In the present context, where the focus is on workplace requirements to manage MSD risk of particular groups of workers, this requires ergonomists to assess MSD risk from both biomechanical and psychosocial hazards of the whole job. And as argued above, this can be achieved by using one or more of the validated questionnaires easily available for this purpose. For reliable assessment of psychosocial hazards, their use is essential.

Use of questionnaires for an initial assessment of hazards and MSD symptom levels, followed by workers' feedback on results, can identify the 'worst' hazards, which in our experience are likely to include both biomechanical and psychosocial ones (Oakman and Chan, 2015). Following this initial broad approach to risk assessment, we suggest that observational methods might then be used ***to evaluate alternative forms of control actions for task-specific biomechanical hazards***, if required. Current workplace practices do not usually follow this pattern.

Perceptions of 'ergonomics'. Ergonomists are recognised as experts in MSD risk management, but 'ergonomics' is widely understood as *only* concerned with risk from biomechanical hazards. For example, the USA's National Institute for Occupational Safety and Health (NIOSH) asserts that: "The goal of ergonomics (i.e. the scientific study of people at work) is to prevent soft tissue injuries and musculoskeletal disorders (MSDs) caused by sudden or sustained exposure to force, vibration, repetitive motion, and awkward posture" (National Institute of Occupational Safety and Health (NIOSH), 2018). This narrow interpretation of 'ergonomics' both influences and is influenced by the current failure to address MSD risk from psychosocial hazards. If *ergonomists* practice and promote a broader 'macro-ergonomics' approach to workplace MSD risk management, it will expand knowledge of 'ergonomics' as well as reduce the incidence of MSDs.

Increase awareness of the need for change. An important prerequisite to achieving change is awareness of the need for it (Haslam, 2002; Whysall et al., 2005; Shaw et al., 2007; Oakman et al., 2016a). In the present case, a key barrier to change is lack of awareness that psychosocial hazards have substantial effects on MSD risk. To address this problem, a good starting point would be revision of MSD-related guidance from OHS regulators, since such information is influential and has been found to affect choice of MSD risk assessment methods in both Australia and Sweden (Oakman et al., 2016b, 2021, 2022; Eliasson et al., 2019). Many MSD guidance documents mention that psychosocial hazards affect risk but provide little if any guidance on how to assess and control these hazards (Macdonald and Oakman, 2015; Macdonald et al., 2003). Ergonomists have been heavily involved in creating such guidance, so are well placed to facilitate revision of its content.

Another potential means of increasing awareness is development and promulgation by national ergonomics societies of 'position statements' and associated press releases about requirements for effective workplace management of MSD risk (Human Factors and Ergonomics Society of Australia Inc., 2020). Such promotional activities could also include presentations to meetings of other OHS professional groups and to key employer or industry groups.

More research on workplace practice issues. There is a need for research on the purposes for which risk assessment methods are used, appropriateness of selected methods for different hazard configurations, and how results are interpreted and communicated to workplace stakeholders. The current paucity of research on workplace practice issues suggests a disjunction between the interests of researchers and workplace requirements.

Shorrock and Williams (2016) identified poor availability of research evidence to practitioners as a factor contributing to the current research-practice gap in ergonomics. Conversely, researchers may lack awareness of key workplace issues affecting OHS practitioners and workplace managers (Diego-Mas et al., 2015), particularly concerning management of risk from psychosocial hazards, which can pose a difficult management challenge (Tappura et al., 2014). Research utilising a broad, macro-ergonomics systems framework is required to support more effective management of MSD risk.

Professional development needs. Measurement and evaluation are required core competencies of professional ergonomists (Oakman et al., 2020), and in the OHS domain this includes competence in MSD risk assessment and control. Research evidence on work-related causes of MSDs is not well reflected in current risk management practices, and awareness of the need for change is low. In addition, there is evidence suggesting that risk assessment methods are not always used appropriately. Eliasson et al. (2017) found skill deficiencies among Swedish ergonomists, who relied mainly on their own 'expert judgements' rather than use a formal method – a practice noted by the researchers as having poor reliability. Asked about influences on their choice of method, they rated importance of it being 'research-based' *lower* than 'ease of interpreting the results (for the client)', 'clear client benefit', 'easy to use', and 'easy to visualize the results'. Diego Mas et al. (Diego-Mas et al., 2017) also found errors in practitioners' implementation of observational methods.

Eliasson et al. (2021) developed an e-learning program to improve ergonomists' knowledge of available risk assessment methods, which promoted improvements in their use. Further development and promulgation of such programs for ergonomists and others responsible for workplace risk management is needed to promote use of methods that are 'fit for purpose'. Involvement of national ergonomics societies in such professional development programs would make an important contribution to translating research evidence into improved workplace practices.

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