



Work-related Musculoskeletal Disorders

Core Body of Knowledge for the
Generalist OHS Professional

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16



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The chapter replaces the 2012 chapter Biomechanical Hazards, which was authored by Dr Robin Burgess-Limerick, and in some sections draws on the content of that chapter.

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Work-related Musculoskeletal Disorders

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Work-related Musculoskeletal Disorders

Abstract

Musculoskeletal disorders are the world's leading contributors to disability, and work-related musculoskeletal disorders (WMSDs) are responsible for more than a third of Australian workers' compensation claims. This chapter presents information about the nature, causation and management of WMSDs. The aim is to enable generalist OHS professionals to take a holistic, participative and evidenced-based approach to WMSD prevention. The chapter includes a multifactorial systems model to assist in the assessment of physical and psychosocial WMSD risks and design of risk controls, and a hierarchy of control for WMSD interventions.

Keywords

Musculoskeletal disorder, sprain, strain, manual handling, biomechanics, psychosocial hazard

Contextual reading

Readers should refer to 1 *Preliminaries* for a full list of chapters and authors and a synopsis of the OHS Body of Knowledge. Chapter 2, *Introduction* describes the background and development process while Chapter 3, *The Generalist OHS Professional: International and Australian Perspectives* provides a context by describing the role and professional environment.

Terminology

Depending on the jurisdiction and the organisation, terminology refers to 'Occupational Health and Safety' (OHS), 'Occupational Safety and Health (OSH) or 'Work Health and Safety' (WHS). In line with international practice, this publication uses OHS with the exception of specific reference to the Australian Work Health and Safety (WHS) Act and related legislation.

Jurisdictional application

This chapter includes reference to Australian work health and safety legislation. This is in line with the Australian national application of the *OHS Body of Knowledge*. Readers working in other legal jurisdictions should consider these references as examples and refer to the relevant legislation in their jurisdiction of operation.

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1 Introduction

One of the six categories of national priority conditions identified in the *Australian Work Health and Safety Strategy 2012-22* (SWA, 2012) is work-related musculoskeletal disorders (WMSDs). According to the *Model Work Health and Safety Regulations* (WHSR):

Musculoskeletal disorder means an injury to, or disease of, the musculoskeletal system, whether occurring suddenly or over time, but does not include an injury caused by crushing, entrapment or cutting resulting principally from the mechanical operation of plant (SWA, 2021b, p. 22).

WMSDs include conditions such as repetitive strain injury, osteoarthritis, sciatica, slipped disc, backache, carpal tunnel syndrome and tendinitis (Oakman et al., 2019). WMSDs are also referred to as, for example, 'occupational overuse syndrome' and 'cumulative trauma disorder' (Hagberg et al., 1995) and 'body stressing,' a term used to describe the mechanism of injury classification in Australian workers' compensation statistics (SWA, 2021b). Also, WMSDs may be described with reference to the site of the pain/discomfort:

- back pain (which can be low back pain, upper back pain or neck pain) in which the source of problems is around the spine and supporting muscles and ligaments;
- upper limb disorders, usually including the shoulders, upper arms, forearms, hand or wrist; and
- lower limb pain, including the hips, legs, knees, ankles and feet) (Crawford & Davis, 2020, p. 10).

WMSDs may affect any worker; causation is multifactorial and symptoms are many and varied. The result can be significant loss of an individual's physical and psychological capacity to live a healthy lifestyle and to perform activities of daily living, and a high cost to businesses and the Australian economy. However, prevention and intervention in any part of the cycle of injury and recovery can make a significant difference to the outcome for individuals, business and the economy.

WMSDs may be sustained as a result of a range of physical impacts on the body (e.g. body stressing; slips, trips and falls; and being hit by, or hitting, objects or people). This chapter, which has been developed with the Human Factors & Ergonomics Society of Australia (HFESA), focuses on WMSDs as a result of body stressing and the impact of psychosocial factors on the expression of these disorders.¹ It aims to enable generalist OHS professionals to perceive WMSDs as multifactorial in causation and control, and to provide a basis for them to work with specialist advisors such as ergonomists. Integral to the chapter is the HFESA (2020a) position statement on WMSDs. Also, several sections are informed by the

¹ For information on causation and management of slips, trips and falls, see *OHS BoK 27 Gravitational Hazards*; for discussion of the impact and management of work-related violence, see *OHS BoK 21 Bullying and Violence*.

2012 *OHS Body of Knowledge* chapter, Biomechanical Hazards, which was written by Dr Robin Burgess-Limerick.

This chapter presents information about the nature, causation and management of WMSDs and supports a proactive, evidenced-based approach to WMSD prevention. Section 2 reflects on the development of our understanding of WMSDs and considers the impact of an Australian RSI 'epidemic.' Section 3 draws on workers' compensation data to elucidate the magnitude of the WMSD problem while acknowledging the limitations associated with using claims data for this purpose. After outlining legislated obligations in section 4, section 5 explores the nature and multifactorial causation of WMSDs. Section 6 emphasises the importance of a risk-management approach and section 7 focuses on the design and implementation of effective interventions. The chapter concludes with a review of the implications for OHS practice and a summary.

2 Historical perspective

Although Leonardo da Vinci (1452–1519) described the biomechanical operation of muscles and bones and physician Bernardino Ramazzini (1633–1714) identified “certain violent and irregular motions and unnatural postures...by which...the natural structure of the living machine is so impaired that serious diseases gradually develop,” it was not until the 1900s that concern developed for minimising biomechanically induced workplace injury (Chaffin et al., 1999, p. 3). This historical neglect of biomechanical injury management has been attributed to manual labour being relatively cheap and easily replaced, and a dearth of information about prevention available to those making decisions in the workplace (Chaffin et al., 1999).

The science of ergonomics developed with the intent of improving workplaces to optimise usability and reduce worker error and injury. In 1953 in Australia, Lane described the practice of ergonomics, outlining the concept of the 'man-machine' interface (of increasing interest since World War II) and the relationship between human capacities and task design (Bullock, 1999). Early work on WMSDs focused on physical factors, including repetition, force and poor posture (e.g. Lawrence, 1955) and, until the 1980s, the predominant foci for preventing injuries associated with manual-handling tasks were setting legislated or suggested weight limits and altering handling techniques. This was based on the assumption that weight and body posture were the prime sources of risk. Since then, epidemiological studies have demonstrated the WMSD-risk involvement of not only physical factors but also psychosocial factors (e.g. low job control, role ambiguity and interpersonal conflict), demographic factors (e.g. age and gender) and individual factors (e.g. body mass index, physical activity rates and smoking) (da Costa & Vieira, 2010).

Today there remains a perception that consideration of psychological factors is something new in WMSDs, despite years of research that takes a broader approach (e.g. Dehlin & Berg, 1977; Elovainio & Sinervo, 1997, Sauter & Moon, 1996; Klaber Moffett & Richardson, 1995), and the proposal of a range of multifactorial models of WMSD causation (Oakman et al., 2019). Unfortunately, gains in our understanding of WMSDs have yet to be adequately translated into workplace practice. For example, Crawford and Davis (2020) found little evidence of effective WMSD-risk-reduction measures within organisations in the European Union. The focus is still on reactive problem solving rather than getting workplace design correct in the first place (Crawford et al., 2020).

2.1 Australia's RSI epidemic

Once described by the Royal Australasian College of Physicians (RACP) as “the most significant public health issue in the history of Australia” (as cited in Awerbuch, 2004, p. 417), the repetitive strain injury (RSI) ‘epidemic’ that occurred in Australia from the late-1970s to the mid-1980s provides insights into the causation, complexity and management of WMSDs that inform OHS and ergonomics today.

Musculoskeletal injuries to the upper limbs resulting from repetitive work were acknowledged as an occupational health problem in NSW factories during the 1960s and 1970s,² but in the late 1970s the incidence of such injuries (as shown by workers’ compensation statistics) escalated dramatically (Stevenson, 1987). Although a small proportion of compensation claims involved clinically recognised conditions such as tendinitis, carpal tunnel syndrome and epicondylitis, the majority involved “non-specific, vague and diffuse symptoms with no clear objective signs or accepted pathophysiological or biomechanical explanation” (Merdith, 2019, p. 248).

The broader workplace and social factors at the time added to the complexity of the problem. The ‘outbreak’ coincided with new computer technology in workplaces, changes in work organisation, efficiency-led reduction in staff numbers and rising unemployment (Reid & Reynolds, 1990; Crawford & Davis, 2020). Opinions and speculation informed sensationalist media attention, and women were disproportionately affected, prompting discussion of ‘mass hysteria’ (Reid & Reynolds, 1990). Australian unions were very active in raising public awareness of the injury claims. Indeed,

The acronym RSI was coined by the non-medical editor of the Australia Council of Trade Unions’ Health and Safety Bulletin and [while some among the medical fraternity had difficulty reconciling the words strain and injury] it was quickly adopted by health

² While considered a relatively new condition by many, pain and other symptoms of the upper limbs resulting from repetitive work had been reported frequently for more than a century (Stevenson, 1987), and the relationships between seating design, posture and workplace layout and the onset of musculoskeletal injuries had been the topic of publications in the 1950s and 60s (Carter & Spurgeon, 2018).

professionals, the media and the public, becoming a household term (Merdith, 2019, p. 248).

In 1982, the National Health and Medical Research Council (NHMRC) published the *Approved Occupational Health Guide – Repetition Strain Injuries*. An RSI committee established in 1984 with representatives of unions, employers and government as well as OHS professionals resulted in the 1986 publication of *Repetition Strain Injury: A Report and Model Code of Practice* in which the National Occupational Health and Safety Commission (NOHSC) recognised RSI as one of Australia’s most serious occupational health problems and acknowledged the potential for workplace psychosocial factors to be implicated in RSI development (NOHSC, 1986; Reid & Reynolds, 1990).

Nevertheless, diagnosis, causation and management of RSI continued to be hotly debated. For example, in 1986 the RACP issued a statement recommending replacement of the label ‘RSI’ with ‘regional pain syndrome’ because without evidence of tissue damage, it was “more properly managed as a pain problem rather than an injury” (RACP as cited in Awerbuch, 2004, pp. 416-417). After noting that RSI had been considered “more likely to be related to life events, stresses and conflicts than to any identified aspects of tasks or occupations” (Lucire as cited in Awerbuch, 2004, p. 418), Awerbuch (2004, p. 418) concluded that “The Australian RSI epidemic burnt out...because in the end doctors stopped certifying as physically injured large numbers of uninjured workers.”

Lessons from the RSI epidemic include:

- Consistent application of diagnostic criteria by the medical profession and a common expectation related to the management of symptoms are important³
- Where there is no dose-response relationship between hazards and outcome, the work-relatedness may not be evident; this does not mean that there is no work-relatedness
- Non-physical factors may play a role in WMSDs.

3 Extent of the problem

An analysis of the Global Burden of Disease 2019 (Cieza et al., 2020; WHO, 2021) identified musculoskeletal disorders as the leading contributor to disability worldwide, significantly limiting people’s mobility and dexterity, and leading to early retirement from work, lower

³ “RSI is no longer treated as a distinct condition, with the signs and symptoms now falling within musculoskeletal disorders” (Merdith, 2019, p. 252).

levels of wellbeing and reduced ability to participate in society. Low-back pain is the musculoskeletal disorder that causes the largest health burden (WHO, 2021). Despite the existence of regulatory requirements to control workplace hazards that might cause these disorders, data from a European Union Labour Force survey showed no significant reduction in incidence of WMSDs between 2010 and 2015 (Crawford & Davis, 2020).

As noted in section 1, the *Australian Work Health and Safety Strategy 2012-2022* identified six categories of conditions as national priorities with the first priority condition being musculoskeletal disorders (SWA, 2012). The cost of WMSDs to the Australian economy was estimated at \$24 billion for the year 2012-2013 (SWA, 2015). Given that the prevalence of musculoskeletal disorders tends to increase as people age (March et al., 2014), and that exposure to WMSD hazards can accelerate this age-related increase (von Bonsdorff et al., 2010), it is significant that the workforce participation rate for Australians aged over 65 increased from 8% in 2006 to 13% in 2018 and is likely to increase further (AIHW, 2018).

Workers' compensation claims data provide further insight into why WMSDs require attention as a priority disorder. However, it is important to note that WMSDs "may result from a single event, but more commonly arise from cumulative exposure to one or more hazards over an extended period [and] these data are not captured accurately in workers' compensation statistics" (Oakman et al., 2019, p. 10). Also, Australian workers' compensation data do not specifically categorise WMSDs; relevant claims are categorised as 'body stressing.'

In 2018-19 in Australia, body stressing was the most common mechanism of injury/disease in 'serious' workers' compensation claims (i.e. accepted claims that resulted in at least a one-week absence from work), with 41,395 claims (36% of all claims) (SWA, 2021a). The majority (80%) of body stressing claims were attributed to handling, lifting, carrying or putting down objects, with most claims involving the back (37%) or shoulder (19%) (Table 1). Although males lodged a higher number of serious body stressing claims than females, body stressing claims represented the same proportion of all claims made by males and by females (Table 2).

From 2013-14 to 2018-19, there was an 11% reduction in claims for body stressing (Table 3). However, from 2013-14 to 2017-18, the median time lost for body stressing claims increased by 13% from 6.0 to 6.8 weeks (SWA, 2021a) and the median cost per claim increased by 29% to \$13,300 (Table 4).

Table 1: Serious claims for ‘body stressing,’ 2018-19 (SWA, 2021a)

		No. serious claims*	% claims for category*
Mechanism	Muscular stress while handling objects	18,350	44%
	Muscular stress while lifting, carrying or putting down objects	14,795	36%
	Muscular stress with no objects being handled	5270	13%
	Total	41,395	
Bodily location	Back – upper or lower	15,445	37%
	Shoulder	8,030	19%
	Knee	3,710	9%
	Abdomen & pelvic region	2,200	6%
	Wrist	2,345	5%
	Hand, fingers & thumb	1,345	4%
	Elbow	1,460	3%
	Neck	1,130	3%
	Total	41,395	

*Figures do not add to total as small categories have been omitted from SWA-published summary data.

Table 2: Serious claims for ‘body stressing’ by gender, 2018-19 (SWA, 2021a)

Mechanism of injury/disease	No. serious claims			% total claims
		Body stressing	Total claims	
Body stressing	Male	26,045	71,465	36%
	Female	15,350	42,965	36%
	Total	41,395	114,435	

Table 3: Number of serious claims for ‘body stressing,’ 2013-14 to 2018-19 (SWA, 2021a)

Mechanism of injury/disease	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	% chge
Muscular stress while handling objects	18,305	18,075	17,345	16,400	17,480	18,350	+2%
Muscular stress while lifting, carrying or putting down objects	18,640	16,970	15,880	15,960	14,955	14,795	-20%
Muscular stress with no objects being handled	6,070	5,605	5,235	5,590	5,300	5,270	-13%
Total*	46,620	44,285	41,625	40,860	40,485	41,395	-11%

*Numbers of claims do not add to the totals because only the most common mechanisms of injury/disease are included.

Table 4: Median compensation paid for serious claims for ‘body stressing,’ 2013-14 to 2017-18 (SWA, 2021a)

Mechanism of injury/disease	Median compensation paid					
	2013-14	2014-15	2015-16	2016-17	2017-18	% chge
Muscular stress while handling objects	\$10,500	\$11,300	\$12,200	\$13,400	\$13,500	+29%
Muscular stress while lifting, carrying or putting down objects	\$9,800	\$10,500	\$11,600	\$12,500	\$12,500	+28%
Muscular stress with no objects being handled	\$9,300	\$10,600	\$11,700	\$11,900	\$12,200	+31%
Total	\$10,400	\$11,400	\$12,300	\$13,300	\$13,300	+29%

4 Legislation and standards

4.1 Legislation

Australian legislation refers to “a musculoskeletal disorder associated with a hazardous manual task” (WHSR s 60; SWA, 2021b, p. 65). Although a somewhat simplistic approach, this covers a range of physical factors related to WMSDs, with the person conducting the business or undertaking (PCBU) required to:

- ...have regard to all relevant matters that may contribute to a musculoskeletal disorder, including:
 - (a) postures, movements, forces and vibration relating to the hazardous manual task; and
 - (b) the duration and frequency of the hazardous manual task; and
 - (c) workplace environmental conditions that may affect the hazardous manual task or the worker performing it; and
 - (d) the design of the work area; and
 - (e) the layout of the workplace; and
 - (f) the systems of work used; and
 - (g) the nature, size, weight or number of persons, animals or things involved in carrying out the hazardous manual task (WHSR s 60; SWA, 2021b, p. 65).

This obligation must be addressed within the context of the general duties under the *Work Health and Safety Act* (WHS Act) that PCBUs must:

- (a) ...eliminate risks to health and safety, so far as is reasonably practicable; and
- (b) if it is not reasonably practicable to eliminate risks to health and safety, to minimise those risks so far as is reasonably practicable (WHS Act s 17; SWA, 2019, p. 14).

PCBUs have the primary duty (WHS s 19) and 'officers' have a duty to exercise *due diligence* to ensure that the PCBU has and uses appropriate resources and processes to eliminate or minimise hazardous manual tasks (s 27).⁴

In addition to their general duties under the Act, designers, manufacturers, importers and suppliers of plant or structures have duties relating to hazardous manual tasks. A designer or manufacturer must:

...ensure that the plant or structure is designed [or manufactured] so as to eliminate the need for any hazardous manual task to be carried out...[or] if it is not reasonably practicable...the need for any hazardous manual task to be carried out in connection with the plant or structure is minimised so far as is reasonably practicable

...give to each person who is provided with the design [or plant or structure]...adequate information about the features of the plant or structure that eliminate or minimise the need for any hazardous manual task to be carried out in connection with the plant or structure (WHSR s 61; SWA, 2021b, pp. 65, 66).

Importers and suppliers of plants or structures are required to take all reasonable steps to:

- (a) obtain the information the designer or manufacturer is required to provide...; and
- (b) give that information to the any person to whom the importer [or supplier] supplies the plant (WHSR s 61; SWA, 2021b, p. 67).

4.2 Codes and standards

The *Hazardous Manual Tasks Code of Practice* (SWA, 2018a) provides practical guidance on identifying, assessing and controlling hazardous manual tasks with the focus on physical risk factors.

The International Organization for Standardization (ISO) publishes a range of relevant standards that focus on the physical aspects and impact of manual handling and postures, including:

ISO 6385:2016 Ergonomics Principles in the Design of Work Systems

ISO 11228-1:2003 Ergonomics – Manual Handling – Part 1: Lifting and Carrying
(Confirmed 2014)

ISO 11228-2:2007 Ergonomics – Manual Handling – Part 2: Pushing and Pulling
(Confirmed 2016)

ISO 11228-3:2007 Ergonomics – Manual Handling – Part 3: Handling of Low Loads at High Frequency (Confirmed 2016)

⁴ For more information about the obligations of PCBUs and officers, and the concepts of reasonably practicable and due diligence, see *OHS BoK 9.2 Work Health and Safety Law in Australia*.

ISO 11226: 2000 Ergonomics – Evaluation of Static Working Postures (Confirmed 2018)

ISO/TR 12296:2012 Ergonomics – Manual Handling of People in the Healthcare Sector

ISO/TS 20646:2014 Ergonomic Guidelines for the Optimization of Musculoskeletal Workload (Confirmed 2018)

ISO/TS 20646-1:2004 Ergonomic Procedures for the Improvement of Local Muscular Workloads – Part 1: Guidelines for Reducing Local Muscular Workloads (Revised 2014)

ISO 26800: 2011 Ergonomics – General Approach, Principles and Concepts.

5 Understanding WMSDs

Understanding the nature of WMSDs is essential for prevention and management. This section explores the complexity of WMSDs and their multifactorial causation.

5.1 Nature of WMSDs

5.1.1 Disorder types

More than 150 conditions are identified as musculoskeletal disorders (WHO, 2021). This wide range of inflammatory and degenerative conditions includes:

...clinical syndromes such as tendon inflammations and related conditions (tenosynovitis, epicondylitis, bursitis), nerve compression disorders (carpal tunnel syndrome, sciatica), and osteoarthritis, as well as less well standardized conditions such as myalgia, low back pain and other regional pain syndromes not attributable to known pathology (Punnett & Wegman, 2004, p. 13).

Various terms have been used to refer to WMSDs, including cumulative trauma disorder, occupational cervicobrachial disorder, occupational overuse syndrome and repetitive strain injury (Hagberg et al., 1995). While common-usage labels for some musculoskeletal disorders reflect an occupational relationship (e.g. carpet layer's knee, golfer's elbow, tennis elbow, writer's cramp), WMSDs are usually classified based on the anatomical structures affected (Table 5).

Table 5: Common WMSDs classified by affected anatomical structure

Anatomical structure	Disorder
Tendons	<p><i>Inflammation</i></p> <ul style="list-style-type: none"> • Tendinitis, peritendonitis, tenosynovitis, insertion tendinitis (enthesopathy), tenoperiostitis • Synovitis of most joints, particularly shoulder, elbow, hand-wrist <p><i>Degeneration</i></p> <ul style="list-style-type: none"> • Epicondylitis (medial and lateral) • De Quervain's disease (stenosing tenosynovitis at the radial styloid) • Dupuytren's contracture (degeneration of the tendons of the palmaris muscle in the hand) • Trigger finger • Ganglion cyst
Muscles	<ul style="list-style-type: none"> • Muscle strain • Tension neck syndrome • Myalgia • Myositis
Joints	<ul style="list-style-type: none"> • Joint sprain involving acute trauma to ligaments resulting in a partial tear, complete tear or avulsion fracture (e.g. ankle roll, joint subluxation or dislocation) • Osteoarthritis of most joints and other degenerative joint diseases • Bursitis (inflammation of small fluid-filled sacs – bursa – that help reduce friction between opposing tissues such as between bone and a tendon or tendon and the overlying skin)
Nerves	<p><i>Nerves become entrapped by musculoskeletal structures</i></p> <ul style="list-style-type: none"> • Carpal tunnel syndrome (median nerve entrapment at the wrist) • Cubital tunnel syndrome (ulnar nerve entrapment at the elbow) • Compression of the median nerve at the wrist • Guyon canal syndrome (ulnar nerve entrapment at the Guyon canal) • Pronator teres syndrome (median nerve entrapment at the elbow) • Radial tunnel syndrome (radial nerve entrapment at the elbow) • Thoracic outlet syndrome (entrapment of the brachial plexus) • Cervical syndrome (radiculopathy) (compression of nerve roots) • Digital neuritis
Circulatory/vascular	<ul style="list-style-type: none"> • Hypothenar hammer syndrome • Raynaud's syndrome (vibration white finger)

5.1.2 Acute and chronic onset

The Australian National Injury Data Set categorises WMSDs into two main groups based on whether the onset of the condition was traumatic (acute) or gradual (chronic).

Traumatic joint/ligament and muscle/tendon injuries (WMSD injuries – usually acute events) include:

- trauma to joints and ligaments (e.g. sprains, tears and dislocation)
- trauma to muscles and tendons (e.g. strains and tears), and
- soft tissue disorders due to trauma or unknown mechanisms.

Musculoskeletal and connective tissue diseases (WMSD diseases – gradual onset or cumulative disorders) include:

- joint diseases (arthropathies) and other articular cartilage diseases (e.g. inflammatory or infectious arthritis, acquired musculoskeletal deformities)
- spinal vertebrae and intervertebral disc diseases – dorsopathies (e.g. back pain, sciatica, neck pain, disc degeneration)

- diseases involving the synovium and related tissue (e.g. synovitis, tenosynovitis)
- diseases of muscle, tendon and related tissue (e.g. non-traumatic muscle or tendon strain, tendinitis, epicondylitis), and
- other soft tissue diseases (e.g. bursitis, occupational overuse syndrome). (Oakman et al., 2019, pp. 14-15)

Trauma can lead to an acute injury as a result of a specific event. For example, a ligamentous injury occurs when a joint is forced beyond its normal range of movement. Such an injury is commonly referred to as a *sprain* “in which some of the fibres of a supporting ligament are ruptured although the ligament itself remains intact [whereas] ...a *strain* may be defined as overexercise or overexertion of some part of the musculature” (Bridger, 2018, p. 165). This type of trauma not only involves the soft tissues (muscle, tendons or ligaments), but also the blood vessels in the area, with histamine release and bleeding resulting in localised swelling of the tissues. As a result of pressure build up, pain and associated loss of function of the area occurs, the level of which depends on the extent of the trauma.

In contrast to an acute event, WMSDs can result from cumulative damage, with impairment built up over time. This type of injury generally occurs as a result of repeated microscopic injuries to the musculoskeletal system. Although the soft tissues can withstand high loads, their capacity to accept and recover from repeated high loads is limited. Once the repair capacity of tissue is exceeded, microtrauma occurs at the cellular level of the involved tissue. Where there is a pre-existing condition and a residual level of inflammation in the tissue, continued activity perpetuates the inflammatory cycle leading to more serious injury. For example, lateral epicondylitis (tennis elbow) is a cumulative musculoskeletal disorder caused by repetitive backhand movement of the forearm muscles.

Additionally, long-term WMSDs may be prone to ‘flare-ups’ creating an ‘acute on chronic’ condition because of an acute exacerbation of a long-standing problem.

While most WMSDs affect the back (37%) and shoulder (19%) (Table 1), many other parts of the body can be affected by acute or chronic conditions (Table 6). Further information about biomechanical impact on various body parts is provided in section 5.3.1.

Table 6: Common acute and chronic WMSDs classified by body part

Body part	Disorder	Comment
Back	<p><i>Acute</i></p> <ul style="list-style-type: none"> • Muscle strain; ligament sprain • Bulged disc or herniated disc with symptoms such as pins and needles, numbness or weakness in the lower limbs <p><i>Chronic</i></p> <ul style="list-style-type: none"> • Low-back pain may come on over time 	Often associated with high load or repetitive manual tasks
Shoulder	<p><i>Acute</i></p> <ul style="list-style-type: none"> • Rotator cuff tear <p><i>Chronic</i></p> <ul style="list-style-type: none"> • Impingement • Bursitis • Osteoarthritis • Frozen shoulder 	Susceptible to injury when structures around the joint are subjected to high load or awkward movement (e.g. reaching above the head and forward while supporting a weight – shoulder joint is designed for high-level mobility rather than high-functional loading)
Lower limb	<p><i>Acute</i></p> <ul style="list-style-type: none"> • Knee meniscal lesions/tears • Stress fracture <p><i>Chronic</i></p> <ul style="list-style-type: none"> • Hip and knee osteoarthritis • Knee bursitis • Varicose veins of the lower leg 	Susceptible to acute injury during high-impact activities when joints are at extreme range of movement; chronic injury can result from, for example, standing on hard surfaces for long periods of time
Upper limb	<p><i>Usually chronic</i></p> <p>Hand</p> <ul style="list-style-type: none"> • Carpel tunnel syndrome • Tendinitis • Tenosynovitis • Osteoarthritis • Cramp of hand or forearm from prolonged repetitive movement • Hand-arm vibration syndrome <p>Elbow</p> <ul style="list-style-type: none"> • Lateral epicondylitis – tennis elbow • Medial epicondylitis – golfer’s elbow 	Due to the reliance on grip strength while performing most manual tasks, tissues of the hands, wrists and forearms may be susceptible to injury because of fatigue through overuse.
Neck	<p><i>Acute</i></p> <ul style="list-style-type: none"> • Herniated disc • Whiplash <p><i>Chronic</i></p> <ul style="list-style-type: none"> • Osteoarthritis of the facet joint 	Overload of the joints and tissue of the neck can occur in sustained forward bending of the neck (flexion)

5.2 Symptoms and diagnosis

The many different WMSDs encompass a wide range of symptoms, including:

- local or generalised pain, aching or discomfort;
- loss or hypersensitivity of sensation to touch, heat or pressure;
- loss of muscle strength, endurance and/or flexibility;
- loss of ability to perform controlled movements, postural or balance reactions; and/or
- physical changes to muscle tone or bulk (atrophy, hypertrophy etc.), skin colour and temperature, inflammation, abnormal alignment of joints, loss of joint range of motion or stability (ASCC, 2006b, p. 11).

There is a tendency for early-stage symptoms to be intermittent (Punnett & Wegman, 2004), and potential for further injury when workers respond to symptoms with awkward movements or unnatural postures and psychological effects impact concentration and stress levels (ASCC, 2006b).

The cumulative nature of the development of many musculoskeletal disorders adds to the difficulty in understanding, diagnosing and controlling them (Oakman et al., 2019). Figure 1 shows the importance of proactive identification of workplace WMSD hazards. “Models for development of WMSD include a pathophysiological process in which it is recognised that if a risk factor exceeds an individual’s capacity a pathological process will result” (HFESA, 2020a, p. 13). This pathological process usually commences before the onset of symptoms, preventing early detection, and often cannot be associated with any specific incident thus leading to underreporting.

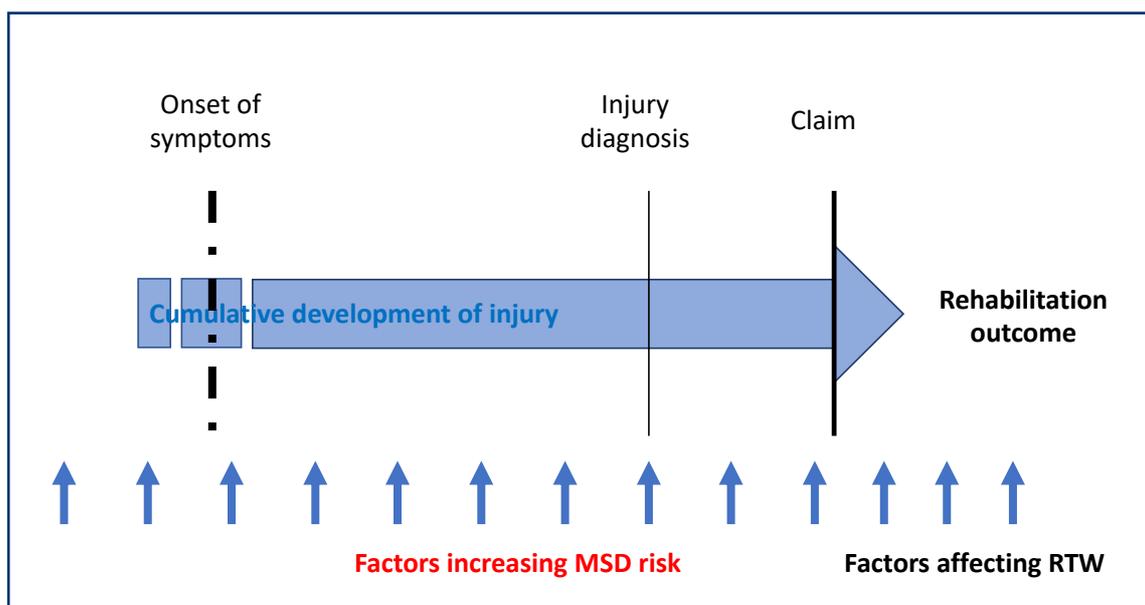


Figure 1: Cumulative WMSD development (Macdonald & Evans as cited in Oakman et al., 2019, p. 31)

Musculoskeletal disorders encompass a continuum from undiagnosed aches and pains to diagnosed conditions, with most people experiencing musculoskeletal pain at some point during their lives. Early recognition of a worker's symptoms can lead to accurate identification of causal factors, earlier diagnosis, quicker recovery, earlier return to work, and reduction in direct and indirect costs. An important factor affecting return to work for individuals with WMSDs is the realisation that people do not need to be pain free to return to work.⁵

5.3 Causation

Exposure to physical and/or psychosocial workplace hazards may result in acute or chronic onset of WMSDs (section 5.1.2). Links between workplace risk factors and symptoms are complex and often difficult to recognise. Many attempts to model WMSDs assume a dose-response relationship between the amount of strain on a person and the resulting level of WMSD (Hagberg et al., 1995). Armstrong et al. (1993) identified four key elements – exposure, dose, capacity and response – in the development of WMSDs of the upper body (Figure 2).

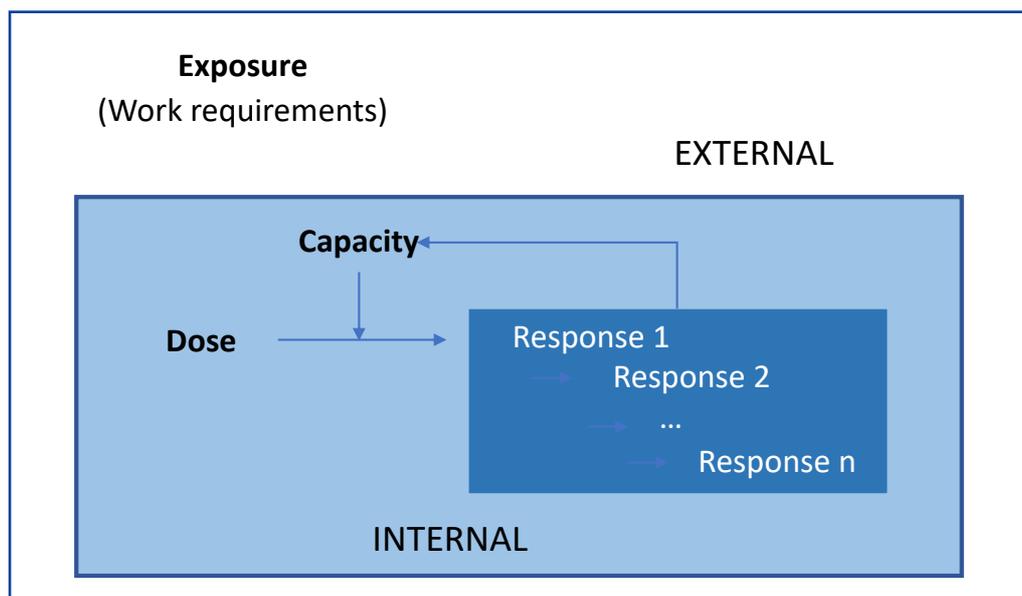


Figure 2: Dose-response model for neck and upper-limb WMSDs (Armstrong et al., 1993, p. 76)

⁵ For information on factors impacting return to work from injury, see *OHS BoK* 35 Mitigation of Health Impacts.

According to this model:

- Workers are exposed to external-to-the-body factors associated with the physical demands of the work (e.g. force, repetition rate), the organisation of work (e.g. work pace, rest breaks) and psychosocial demands (e.g. job dissatisfaction, quality of supervision)
- These work demands stimulate physical, physiological and psychological changes in the body (the dose)
- These changes (the dose) initiate a range of responses
- If the responses are beyond the body's capacity to cope (physically, physiologically or psychologically) then a WMSD is experienced (Armstrong et al., 1993; Bridger, 2018).

Therefore, it is not difficult to appreciate the importance of a well-designed task that accommodates the capacity of body tissues to withstand and adapt to the mechanical stresses to which they are exposed. With poor work design, on the other hand, trauma may compromise the capacity of tissues to undergo repair and recovery. Importantly, it may be challenging to link different parts of the model because physical risks are often evaluated separately from psychological risks and the diversity of the workforce may not be considered.

The complexity of WMSDs requires a holistic, systems-based approach. This can be achieved by applying a human factors and ergonomics lens that considers:

...user characteristics, technology, skills and knowledge, tasks required to be performed and their performance level, and an understanding of the environmental and psychosocial conditions in the workplace related to the design of the human-machine-environment system (HMES) of work (HFESA, 2020c, p. 4).

Figure 3 presents a model of the relationship between different human factors and ergonomics elements – worker, job/task, workplace and equipment, and work organisation. Although each element can be evaluated separately, assessment of the interaction of all four elements will provide the key insights.

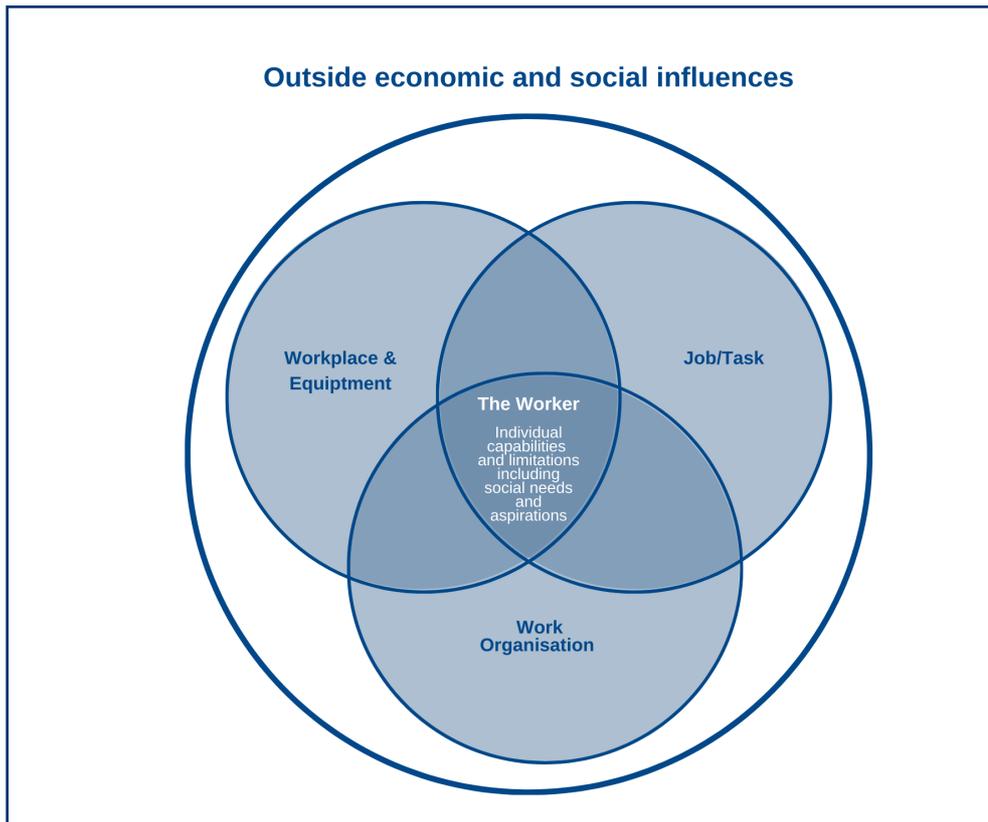


Figure 3: Human factors and ergonomics relationship model (Scott, Kogi & McPhee, 2010, p. 23)

Figure 4 illustrates how a poor fit between worker characteristics and workplace factors can increase WMSD risk. Body stressing effects of overload of body tissues are brought about by the imposed demands of poor work design. Effects on a worker can involve multiple body systems (e.g. hormonal and nervous system organs) and induce other physical, physiological and biomechanical altered states. Imbalance can create a stress response, potentially leading to changes in worker behaviour (e.g. resorting to an unsafe work method, using excessive force to perform a task, not taking a work break when fatigued) that increase WMSD risk.

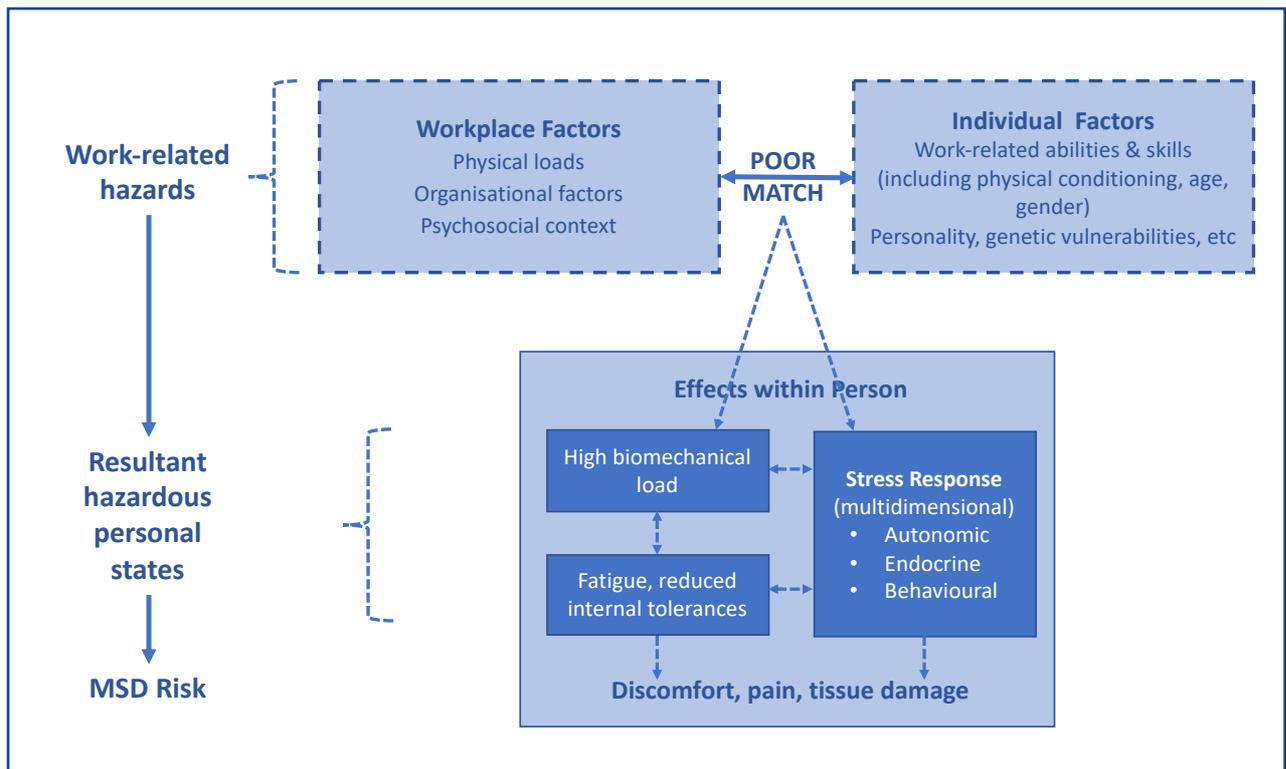


Figure 4: A simplified composite model of causation for WMSD risk (Macdonald & Oakman, 2015, p. 3)

Considering the large and diverse range of factors known to influence WMSD risk, Oakman et al. (2016) proposed an ergonomics systems model with layers representing:

- External factors
- Workplace environmental factors
- Work organisation and job design factors
- Task and equipment factors
- Workers' individual factors.

Figure 5 expands Oakman et al.'s (2016) multi-layered system with detail about risk factors. It provides a conceptual view of the causation of WMSDs and a reference point for risk assessment and the design of risk controls. Sections 5.3.1 and 5.3.2 consider the model's two categories of workplace environmental factors – physical and psychosocial.

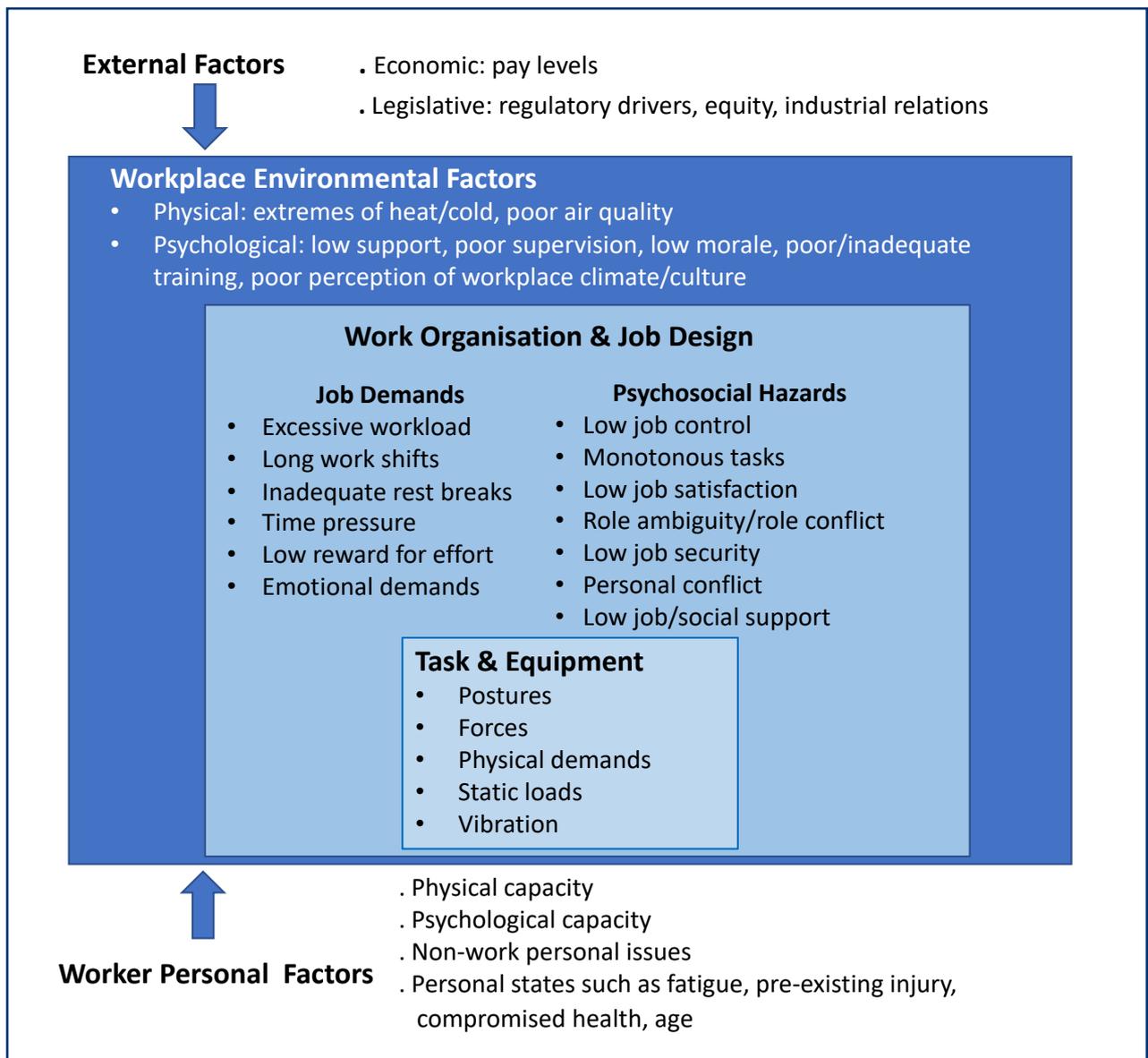


Figure 5: Ergonomics systems model (Oakman et al., 2016, 2019) expanded to include examples of factors influencing WMSD risk

5.3.1 Physical factors

The breadth of physical risk factors is addressed in regulatory and industry guidance (section 4), and the *Hazardous Manual Tasks Code of Practice* (SWA, 2018a) provides

more detail and illustrated examples. Two types of physical factors impacting WMSDs are considered below – biomechanical and vibration.⁶

Biomechanical

WMSDs can result when the forces on body tissue (e.g. muscle, tendon, ligament, bone) are greater than the tissue can withstand. As explained in section 5.1.2, biomechanical injuries can occur suddenly after a single exposure to a high force (e.g. muscular back pain after an awkward lift) or as a response to cumulative exposure to lower levels of force. Body tissues can be injured at a lower force threshold and repaired before pain is felt. If the rate of damage is faster than the rate of recovery, then an MSD may result. Rate of recovery can also impact the likelihood of injury at lower forces if a tissue has been weakened by cumulative damage.

Different tissue types respond to injury in distinctive ways:

Bones

- Although fracture of bone can occur as a consequence of a single application of high load, in occupational situations stress fractures as a result of accumulation of microdamage in excess of the tissue's capacity to repair is more common. Damage to bone associated with biomechanical load often occurs as fractures in vertebral endplates as a consequence of prolonged exposure to repetitive forceful exertions and awkward postures (Adams & Dolan, 1995).

Muscles

- Acute injury to muscle occurs as a consequence of loading that exceeds the tolerance of the tissue; this is particularly likely during eccentric contractions (e.g. when working with gravity such as lowering a load or walking downstairs) (Edwards, 1988).
- Cumulative injury may occur as a consequence of prolonged exposure to isometric muscle activation where the muscle is activated but in a static and/or awkward posture (e.g. working with hands overhead) or repeated similar movements (Kilbom, 1994). Muscle-fibre strength is highly dependent on fibre length, which varies with joint posture and, consequently, extremes of joint posture may place muscle fibres at increased risk.

Tendons and ligaments

- Tendons and ligaments are susceptible to acute injury through exposure to high loads. Compared to muscles, they have a relatively slow repair rate due to poor blood supply. Acute injury is more likely when forces are exerted on a joint at the end of its range of motion.

⁶ This section is informed by the 2012 *OHS BoK* chapter Biomechanical Hazards (archived).

- Cumulative damage to tendons appears to occur most frequently when the tendons are loaded simultaneously in tension (muscle contraction) and transverse reaction forces.
- As is the case for muscles, risk factors associated with tendon, ligament and cartilage injury are forceful exertions and prolonged exposure to repetitive forceful exertions in awkward postures.

Nerves

- Nerve compression typically occurs where nerves pass through other structures (e.g. the carpal tunnel of the wrist or sciatic pain via the lumbar nerve root).
- Although acute nerve compression reverses (with recovery ranging from weeks to years), chronic compressions (e.g. carpal tunnel syndrome) can cause permanent damage (Menorca et al., 2013).

Blood vessels

- Prolonged exposure to forceful exertions can lead to arterial occlusion caused by clot formation. This is typically observed in the hand where a task involves repetitive striking or twisting an object.

Because it is difficult to measure the exact impact of loading, biomechanical models are used to estimate loads on body structures, with this data informed by mechanical testing of cadaveric specimens. Epidemiological data is then used to identify links with task activities and subsequent injuries. Assessing the risk of injury from biomechanical hazards can be complicated due to the potential for different aspects of a task to contribute to risk and the interaction between risk factors (e.g. repetitive work with static postures due to supporting tools). Other risk factors such as vibration and psychosocial hazards need to be assessed simultaneously.

Vibration

Exposure to vibration is associated with the development of WMSDs. Typically, *hand-arm vibration* is the result of exposure to high-frequency vibration from sources such as power tools, with damage caused to the nerves and blood vessels. Acute exposure can result in blanching of the fingers and loss of sensation and control (Raynaud's syndrome or vibration white finger). This can become permanent with long-term exposure to vibrating tools. Long-term exposure to *whole-body vibration* (such as may be experienced in certain vehicles) is strongly associated with back pain. As well as a direct effect on the back, exposure to whole-body vibration has an indirect influence on injury risk by causing fatigue of the back muscles. The risk is greater when the amplitude of vibration is high (e.g. heavy vehicles and/or rough terrain).⁷

⁷ For more information about the mechanism and impacts of vibration, see *OHS BoK 22.2 Vibration*.

5.3.2 Psychosocial factors

A significant body of research has demonstrated that WMSD development is associated with not only physical exposures in the workplace but also psychosocial work characteristics via “increases in muscle tension; changes in endocrine, immune, neurological, and vascular systems or higher cognitive processes that alter the perception and evaluation of symptoms” (Taibi et al., 2021, p. 2).

Psychosocial hazards are those aspects of work design, the organisation and management of work and the social and environmental context that have the potential for causing social or physical harm (Bridger, 2018). They include the ability for workers to influence workload or work methods and changes in the workplace and performance requirements or processes for dealing with conflicts, inadequate workplace training for work organisation and work environment factors... (HFESA, 2020a, p. 15)

While evidence for the role of psychosocial factors in the causation of WMSDs has been mounting for some time, OHS practice has tended to lag behind the research findings. Systematic reviews (e.g. Hauke et al., 2011; Lang et al., 2012) have elucidated the role of workplace psychosocial factors as important independent predictors of WMSDs affecting different body regions (Oakman et al., 2019). Table 7 summarises this evidence.

Table 7: Summary of relationships between psychosocial factors and WMSDs based on the findings of Hauke et al. (2011) and Lang et al. (2012) (Oakman et al., 2019, p. 28)

Psychosocial factors	Neck/shoulders	Upper extremities	Low back
High job demands	+	++	++
Low job control	++	+	++
High job strain	++		++
Low social support	+	+	+
Low job satisfaction		+	+
Low job security			++

+ = 1 study showed significance; ++ = 2 studies reported significance

Taibi et al. (2021) analysed post-2017 studies of the relationship between psychosocial work characteristics and WMSDs and found strong evidence that the risk of WMSDs increased with “High job demands, high job strain, high effort-reward imbalance, low social support, and low perceived fairness” (p. 9). In addition, Taibi et al. found reasonable evidence that risk factors include “Low job control, low work time control, high workplace bullying, high hindrance stressors, high role conflict, and interpersonal conflicts” (p. 9).

There are many ways of modelling or representing psychosocial hazards, one of which is the Job Demands-Resources Model⁸ where psychosocial factors are depicted as either work resources or work demands. Organisations can influence the 'balance' between resources and demands and so manage job stress by increasing resources (Figure 6). Importantly, whether a work characteristic is a resource or a demand is dependent on the way it is perceived by workers, adding importance to the worker consultation process.⁹

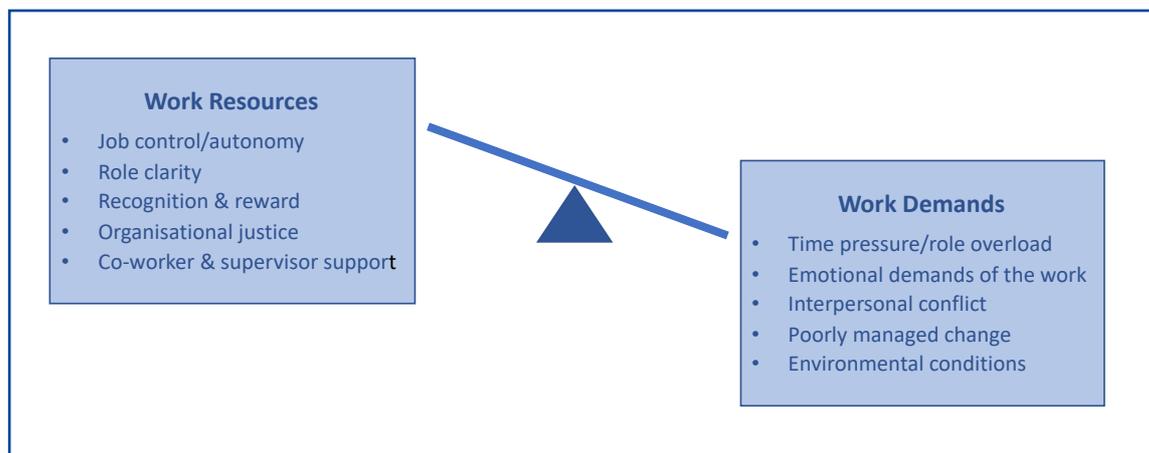


Figure 6: Psychosocial hazards illustrative framework – potential imbalance between work demands and work resources¹⁰

Although there is clear evidence of the link between psychosocial factors and WMSDs, our understanding of how the effect is mediated is less developed. Hauke et al. (2011) summarised the main features of different explanatory models, illustrating the potential impacts of psychosocial factors on WMSDs (Figure 7). Further research is needed to explain the process and the complexity of interactions between physical and psychosocial risks and WMSDs. This highlights the need to take a consistent biopsychosocial approach in the management of these disorders.¹¹

⁸ See *OHS BoK 34.4 Design of Work* (in development at time of writing) for an explanation of the Job Demands Resources Model and other related models.

⁹ See *OHS BoK 19 Psychosocial Hazards*.

¹⁰ *OHS BoK 19 Psychosocial Hazards*, p. 12.

¹¹ For more information about biopsychosocial approaches, see *OHS BoK 6 Global Concept: Health*.

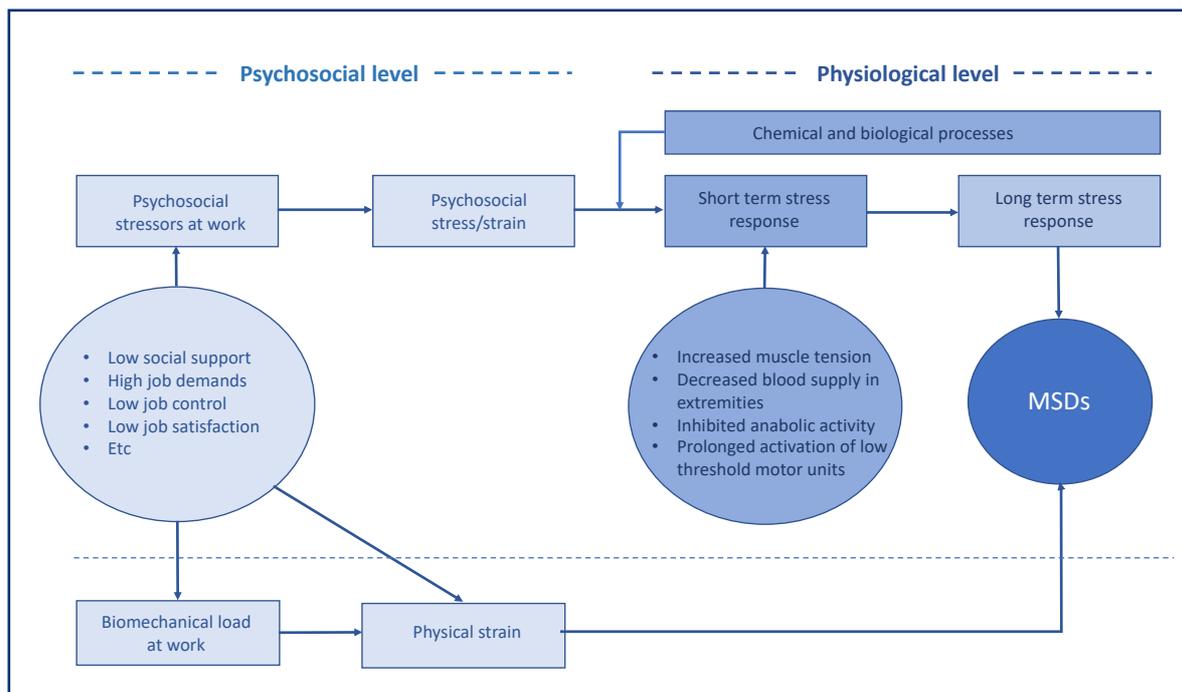


Figure 7: Explanatory model of the impact of psychosocial factors on WMSDs, based on published models (Hauke et al., 2011, p. 245)

6 Risk management

A risk-management approach is recommended for the management of WMSDs (e.g. SWA, 2018a). As depicted in Figure 8, this features a core process of identify, analyse, evaluate and control (or treat) with enabling processes for communication, consultation, monitoring and review. The risk-management process should consider the overall job rather than individual tasks so that the multifactorial nature of WMSD causation (Figure 5) is addressed.

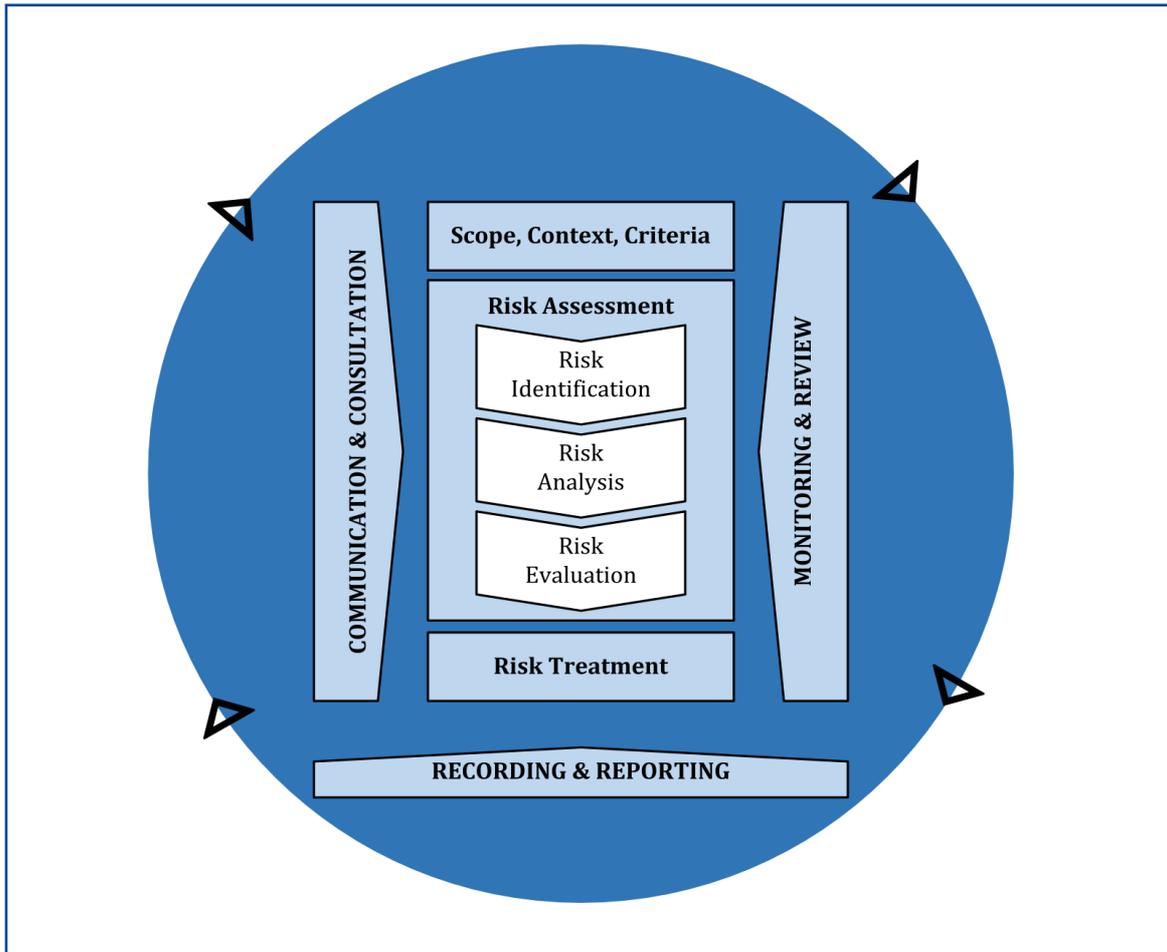


Figure 8: Risk-management process (ISO, 2018, p. 9) (Reproduced with the permission of Standards Australia Limited on behalf of ISO © ISO 2018 – All rights reserved)

6.1 Hazard identification

As indicated in section 4.1, proactive detection of the presence of risk factors for WMSD is essential for early intervention. As required by the *Model Work Health and Safety Regulations*, identification of hazardous manual tasks that may contribute to a WMSD must “have regard to all relevant matters...including”:

- (a) postures, movements, forces and vibration relating to the hazardous manual task; and
- (b) the duration and frequency of the hazardous manual task; and
- (c) workplace environmental conditions that may affect the hazardous manual task or the worker performing it; and
- (d) the design of the work area; and
- (e) the layout of the workplace; and
- (f) the systems of work used; and
- (g) the nature, size, weight or number of persons, animals or things involved in carrying out the hazardous manual task. (WHSR, s 60; SWA, 2021b, p. 65)

The *Hazardous Manual Tasks Code of Practice* suggests that hazards may be identified by talking with workers and observing the workplace, with particular focus on:

- work tasks and how they are performed
- work design and management
- the tools, equipment and objects handled, or
- physical work environment.

A manual task is considered hazardous if it involves any of the following characteristics:

- repetitive or sustained force
- high or sudden force
- repetitive movement
- sustained and/or awkward posture, or
- exposure to vibration (SWA, 2018a, pp. 11, 12).¹²

While the physical factors identified in traditional hazard identification tools are important in the causation of WMSDs, they do not adequately address the multifactorial causation of WMSDs. As indicated in section 5.3.2, it is well established that psychosocial factors often play a significant role.

A common perception is that physical hazards are more important than psychosocial hazards in terms of WMSD development. In reality, there is huge variation in the contribution of these two hazard groups to WMSD risk...It is clear that psychosocial hazards are not peripheral to physical factors. That is, psychosocial hazards can be directly involved in the development of an injury and, in some cases, are more important than physical hazards. (Oakman et al., 2019, p. 31)

Worker consultation and participative processes (section 7.6.2) are essential in identifying the potential for WMSDs as the impact of physical or psychosocial factors may not be observable. Evidence that workers' own ratings may be more valid indicators than observation-based measures (Barrero et al., 2009) suggests that discomfort surveys may be useful in identifying the potential for WMSDs.¹³

6.2 Risk assessment

Risk assessment is usually undertaken to understand the nature of the risk and/or to estimate the level of risk.¹⁴ Given the complexity of WMSD causation (section 5.3), attempts to quantify the level of WMSD risk associated with any manual task or work situation are likely to be contentious and of limited value in preventing or minimising the risk. However,

¹² The *Hazardous Manual Tasks Code of Practice* (SWA, 2018) explains these risk factors and applies them to a hazardous manual task risk management process and a hazardous manual task identification worksheet.

¹³ An open-source Participative Hazard Identification and Risk Management (APHIRM) toolkit with a comprehensive musculoskeletal discomfort/pain survey is available at www.aphirm.org.au

¹⁴ See *OHS BoK* 31.1 Risk.

risk assessment can support more effective risk control by enabling better understanding of the nature of the risk.

There are various specialist ergonomic tools (Appendix 1) that, in the hands of those experienced in their use, can provide greater understanding of the WMSD risk associated with particular tasks. Some of these tools focus on biomechanical aspects of an activity, and others take a broader view of risk factors.

Whatever risk-assessment methodology is used it is vital that those doing the work are involved in the assessment and that data is not just observational. A participatory approach (section 7.6.2) enables those workers who carry out tasks to be involved as part of the solution when higher-risk tasks are identified (Buckle, 2021). Augmented reality and virtual reality technology may be valuable in facilitating the engagement of workers in hazard identification and risk assessment.

The *Hazardous Manual Tasks Code of Practice* advises that formal risk assessments are not required where the “hazards and their associated risks are well known and have well established and accepted control measures” (SWA, 2018a, p. 19). When making such assumptions it is vital to recall the objective of risk assessments – to understand the nature of the risk and the risk factors as a basis for control. Given the complexity of causation and exacerbation of WMSDs, a formal checklist may not always be appropriate; however, this complexity must be understood in the design and implementation of WMSD controls. To address this complexity, risk assessment for WMSDs should take account of the broad range of risk factors in Figure 5.

6.2.1 Workplace environment

Research has indicated a link between WMSDs and environmental conditions such as temperature, noise and light. Magnavita et al., (2011) found that not only were physical environmental conditions (especially ambient temperature) related to WMSDs, but that the physical conditions exacerbated the impact of psychosocial risk factors. “The exact mechanism through which environmental and psychosocial stress factors at work relate to MSDs is not known” (Magnavita et al., 2011, p. 199) nor is there any specific risk-assessment tool. If workplace conditions such as thermal environment, noise, vibration, underfoot conditions, lighting or air quality are identified as potentially contributing to WMSD risk, then standard risk-assessment processes for these hazards could be used.¹⁵

¹⁵ See *OHS BoK 26 Thermal Environment*; *OHS BoK 22.1 Noise*; *OHS BoK 22.2 Vibration*; *OHS BoK 27 Gravitational Hazards*; *OHS BoK 17.2 Fibres, Dusts and Particles* (in development at time of writing)

Figure 5 includes the psychological environment as an environmental factor. A safety climate survey may provide a useful ‘screening’ or sensitivity tool for identifying and assessing risks in the workplace psychological environment.¹⁶ However, the psychological environment is inextricably linked to the psychosocial hazards of work organisation and job design as are the risk-assessment processes (section 6.2.2).

6.2.2 Work organisation and job design

The *OHS Body of Knowledge* chapter 19 Psychosocial Hazards (pp. 25-27) discusses approaches to assessing risk of these hazards. The Appendix to this chapter provides a list of risk-assessment tools for WMSDs, some of which include psychosocial hazards. Two Australian risk-assessment tools that address psychosocial hazards are the open-source *People at Work (PAW)*¹⁷ survey tool developed by a consortium of Australian universities and OHS regulators, and A Participative Hazard Identification and Risk Management (APHIRM) toolkit provided by La Trobe University.¹⁸

6.2.3 Task and equipment

The *Hazardous Manual Tasks Code of Practice* (SWA, 2018a) provides guidance on assessing physical risk factors associated with task and equipment.¹⁹ Table 8 explains the mechanisms of action of these risk factors.

Table 8: Mechanism of action for physical risk factors²⁰

Risk factor	Explanation
Movement	The optimal design of work provides tasks involving slow-to-moderately paced movements and varied patterns of movement.
Repetitive movement	As a qualitative description, repetition is work that is monotonous and has little variation. As a quantitative description, repetition is the frequency of actions or work activities typically including output-based measures (e.g. picks/hour, keystrokes/hour) and movement-based approaches (e.g. cycle time, number of tasks per cycle, cycles times of 30 seconds or less, movement or force performed more than twice a minute) (Bridger, 2018). From the perspective of reporting, repetitive use is the cyclical use of the same tissues and should be assessed in terms of the muscle or joint involved, the cycle

¹⁶ For information about safety climate surveys, see *OHS BoK* 10.2.2 Organisational Culture: Reviewed and Repositioned.

¹⁷ See *People at Work*: www.peopleatwork.gov.au

¹⁸ See Oakman and Macdonald (2019) and *APHIRM* at www.aphirm.org.au

¹⁹ SWA (2018a) includes a detailed risk-assessment checklist as Appendix F.

²⁰ This table is informed by *OHS BoK* 16 Biomechanical Hazards (archived) and *OHS BoK* 22.2 Vibration.

Risk factor	Explanation
Lack of movement	<p>time and the number of units per cycle time, with static components reported separately.</p> <p>Repetitive work has been well documented as a WMSD risk factor (Hagberg et al., 1995). Tasks that are repetitive induce fatigue in tissue and, along with other risk factors, may increase risk of tissue damage leading to injury. For example, a muscle's endurance capacity can be exceeded in combination with high loads handled repeatedly while an increase in blood supply to a working muscle may also be associated with a decrease in blood supply to the tendons and ligaments of the associated joint (e.g. plantar fasciitis) (Bridger 2018).</p> <p>Little or no movement of a body part elevates the risk of discomfort and injury because the flow of blood through muscles to provide energy and remove waste depends on movement. Tasks involving static postures quickly lead to discomfort, especially if combined with exposure to other risk factors.</p>
Posture	<p>When joints are exposed to postures involving extremes of the range of movement, the tissues around the joint are stretched and the risk of injury is increased. Ligaments, in particular, are stretched in extreme postures. If the exposure to extreme postures is prolonged, the ligaments do not immediately return to their resting length. Tissue compression may occur as a consequence of extreme postures (e.g. extreme postures of the wrist increase the pressure on the nerve that passes through the carpal tunnel). Strength of muscles is influenced by the posture of the joints over which they cross. Muscles are weaker if they are shortened; this effect will be greatest when the joints approach the extreme of the range of movement.</p> <p>Some non-extreme joint postures are known to be associated with increased risk of discomfort and injury (e.g. trunk extension, lateral flexion or rotation; neck extension, lateral flexion or rotation; and wrist extension or ulnar deviation).</p>
Duration	<p>If a task is performed continuously for a long time without a break, the tissues involved do not have opportunity for recovery, and cumulative injury risk increases. This is especially likely if the task involves a combination of moderate force or repetitive movement, and awkward postures. Changing tasks can provide recovery if the second task involves different body parts and movement patterns. The appropriate task duration also depends on environmental factors such as heat/cold.</p>
Force	<p>While mass of the object being handled is a factor in force, other factors relate to the type of movement:</p> <ul style="list-style-type: none"> • Lifting and lowering – the further the load is held away from the body the higher the force • Pushing or pulling – frictional properties of the both the load and the surface can increase/decrease force • High-speed, jerky movements (e.g. hammering, throwing) create a high force and reduce the strength of muscles creating the movement • Impact forces, especially to the hand, create tissue damage • Large muscles, such as quadriceps (upper legs), can produce high forces without injury whereas small muscles of the hand and forearm may be injured by relatively small forces.²¹
Vibration²²	<p>The evaluation of human vibration is complex and requires consideration of many factors apart from measurement of the surface vibration. As standards cannot account for all human variables, they tend to concentrate on vibration level, duration, magnitude, frequency and direction.</p>

²¹ See OHS BoK 16 Biomechanical hazards (archived).

²² See OHS BoK 22.2 Vibration.

Risk factor	Explanation
Whole-body vibration (WBV)	<p>Factors that influence the development of harmful WBV effects include:</p> <ul style="list-style-type: none"> • Individual characteristics, e.g. worker health status, pregnancy, diabetes, worker size and weight, driver skill, familiarity with the terrain, ability to change posture, years of exposure • Work environment, e.g. condition of road surfaces, speed limits, shocks and jolts, operating durations and exposures, vehicle/vessel cabin conditions, visibility without need for twisting or stretching, controls within easy reach, air-conditioned cabin, weather conditions, exposure to vapours and fumes • Plant characteristics, e.g. design, condition, size, engine and cabin vibration damping, vehicle suspension and tyres, suspension-dampened seats, cabin layout, plant operating activities, traveling speed.
Hand-arm vibration (HAV)	<p>Factors that influence the development of harmful HAV effects include:</p> <ul style="list-style-type: none"> • Individual characteristics, e.g. operator posture (including awkward postures), gripping the tool's handlebars more tightly than necessary, unfamiliarity with the process or inadequate operator training, susceptibility to blanching of the fingers due to cold weather conditions (primary Raynaud'), health status, diabetes, smoking • Tool characteristics, e.g. the wrong tool for the operator (too big and/or too heavy), wrong tool for the activity, incorrect combination of tool and consumables, worn tools, handle bars not vibration insulated, hardness of material being worked on • Work organisation, e.g. a worker's daily exposure to vibration, trigger time of the worker using the tool, work and rest periods, temperatures, opportunities to keep hands warm and dry.

6.2.4 Worker

Risk assessments must also consider individual worker factors such as physical and psychological capacity and personal states such as fatigue, pre-existing injury, compromised health and age (Figure 5). Hazardous manual handling and WMSD risk-assessment methods are often blind to such individual worker factors.

6.3 Risk control

An investigation of the range of control measures used by organisations in the European Union revealed that not all organisations were carrying out risk assessments for WMSDs and that tools used in the risk-assessment process focused on risk identification without solutions, with most used as an afterthought when problems were identified rather than during workplace design (Crawford et al., 2020).

The primary aim of risk control is prevention of WMSDs through the design of workplaces, work, equipment and tasks. Injury risk is elevated when there is significant exposure to multiple risk factors. Intervention to control WMSDs may occur at three levels:

1. Primary intervention to proactively eliminate or reduce exposure of workers
2. Secondary intervention to promote early detection and minimise impact
3. Tertiary intervention, which is reactive and includes return to work and rehabilitation.

The high incidence of musculoskeletal disorders dictates that primary, secondary and tertiary intervention should be employed simultaneously. This chapter focuses on primary intervention, which is the most important but often the most difficult form of intervention to implement.²³ It requires an understanding of the nature of WMSDs and the willingness and ability to intervene, often with limited evidence of a problem.

The concept of a hierarchy of risk controls is commonly used in developing interventions to control workplace hazards.²⁴ Hierarchies of control are based on the premise that higher-level controls, which prioritise elimination of the hazards or reduction of the risk by substitution with a less-risky option or engineering controls, give more reliable risk control than administrative controls or provision of personal protective equipment. Interventions for WMSDs must be multifaceted to address the multifactorial nature of causation and to account for the inherent needs of the work while prioritising those controls with the highest level of protection and reliability. Figure 9 presents a hierarchy of control for WMSDs that is informed by HFESA (2020a), which, in turn, drew on Oakman et al. (2019) and SWA (2018a). Figure 9 includes factors identified in Figure 5 and current practice.

²³ For information on tertiary intervention, see *OHS BoK 35 Mitigation of Health Impacts*.

²⁴ See *OHS BoK 34.1 Prevention and Intervention*.

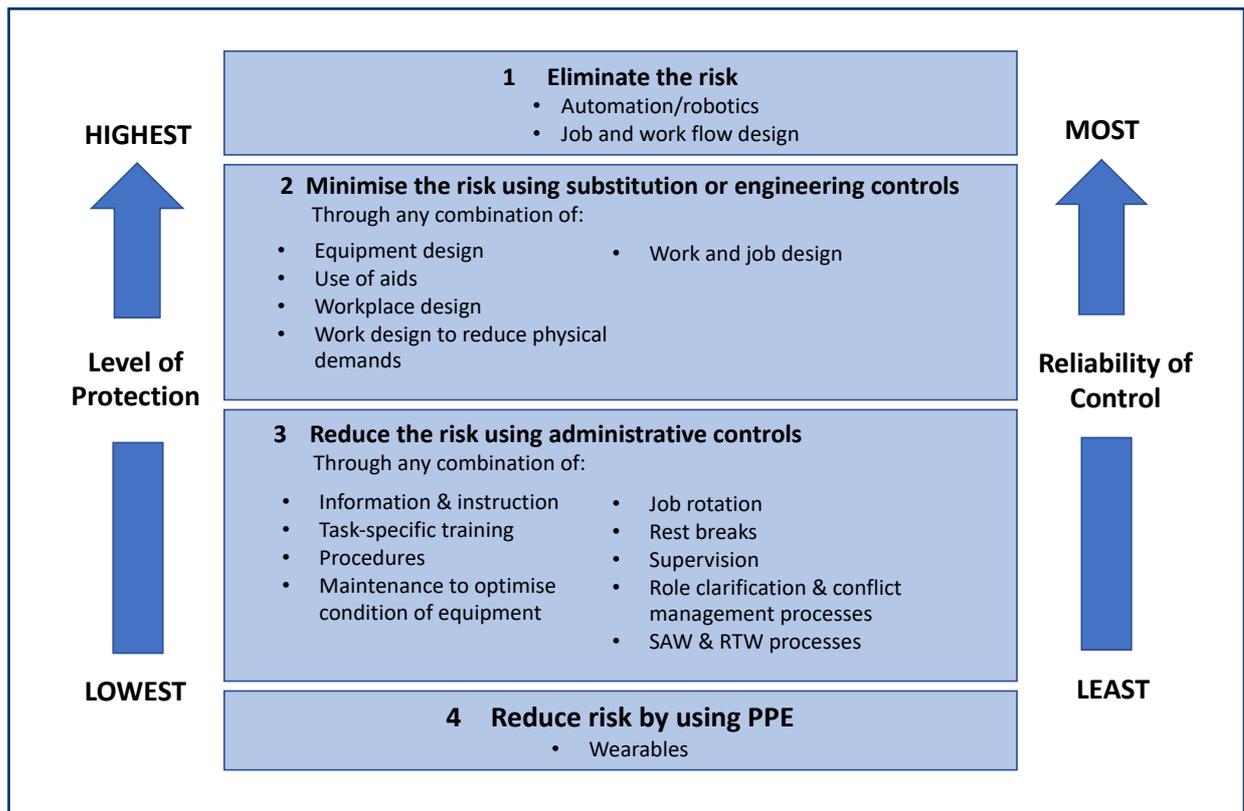


Figure 9: Hierarchy of control for WMSD intervention

7 Intervention

As indicated in section 6.3, design to either eliminate hazardous tasks or conditions or to minimise risk by substitution with less-hazardous tasks or conditions should be the top priority in managing WMSD risk. This section explores the application of design to manage WMSD risk then considers other options in the WMSD hierarchy of control – engineering controls, administrative controls and personal protective equipment. It is vital that selection and design of interventions take account of the strength of the evidence supporting their effectiveness.

7.1 Design

Design that considers WMSD risk should account for physical and psychosocial factors and extend to the task and equipment, job and work organisation, and work environment.

7.1.1 Task and equipment

The 1990s saw the development of the concept of safe design, which has been defined as:

...the integration of hazard identification and risk assessment methods early in the design process to eliminate or minimise the risks of injury throughout the life of the product being designed. It encompasses all design including facilities, hardware, systems, equipment, products, tooling, materials, energy controls, layout, and configuration. (ASCC, 2006a, p. 5.)

Also referred to as 'safety by design' or 'good work design,' the ergonomics principle of designing for the user is well established and underpins all discussion of safe design (ASCC, 2006a). However, as explained in the *OHS Body of Knowledge* chapter 34.3 Health and Safety in Design, the concept of the 'user' is often limited to the end user. To be effective, health and safety by design must encompass all 'users' who construct/manufacture, commission, operate, maintain/clean or demolish/dispose the designed product. Designing for this range of users requires a broad view of 'use' and a design process that includes:

- Engagement of people in the design process
- Analysis of the system within which the designed product will be used by a human
- A controlled sequence of decision making to develop and implement the design
- Consideration of health and safety risk at each stage of the design process.²⁵

The design priority for hazardous manual tasks is, where practicable, elimination through strategies such as the use of robotics or workflow that eliminates multiple handling (SWA, 2019). Where elimination of the hazardous manual task is not practicable, design may enable substitution by tasks and conditions of lesser risk. Figure 9 includes some examples of design factors for equipment and tasks to reduce the risk associated with hazardous manual handling.²⁶

7.1.2 Work organisation and job design

The importance of the design of jobs and the organisation of work was emphasised by the Royal Australasian College of Physicians (RACP) and the Australasian Faculty of Occupational and Environmental Medicine (AFOEM) in their position statement *What is Good Work?* (RACP, 2013), which identifies the following domains:

- Good work by design
- Engagement of workers
- Engagement of community

²⁵ For information about the design process, the role of OHS professionals in design, and a tool to support OHS professionals to engage in the design process, see *OHS BoK* 34.3 Health and Safety in Design.

²⁶ See also SWA (2018a, pp. 34-42).

- Procedural justice and relational fairness
- Work design (RACP, 2013).

A Human Factors & Ergonomics Society of Australia (HFESA) position paper described good work design as:

...a systematic approach (i.e. follows specific stages customised to each workplace) and is based on systems thinking (i.e. considers interactions and dependencies among all workplace elements such as staff, technology, and the environment). (HFESA, 2020b, p. 3)

HFESA (2020b) outlined a three-stage process for good work design – discovery, design, realisation (Figure 10).²⁷ This takes a people-centred approach (consistent with the participatory approaches described in section 7.6.2) that considers the “entire operating envelope (i.e. execution of tasks under different conditions),” including the limitations and constraints, with each design stage being a collaborative process (HFESA, 2020b). The model acknowledges that the realisation of beneficial outcomes may take some time.

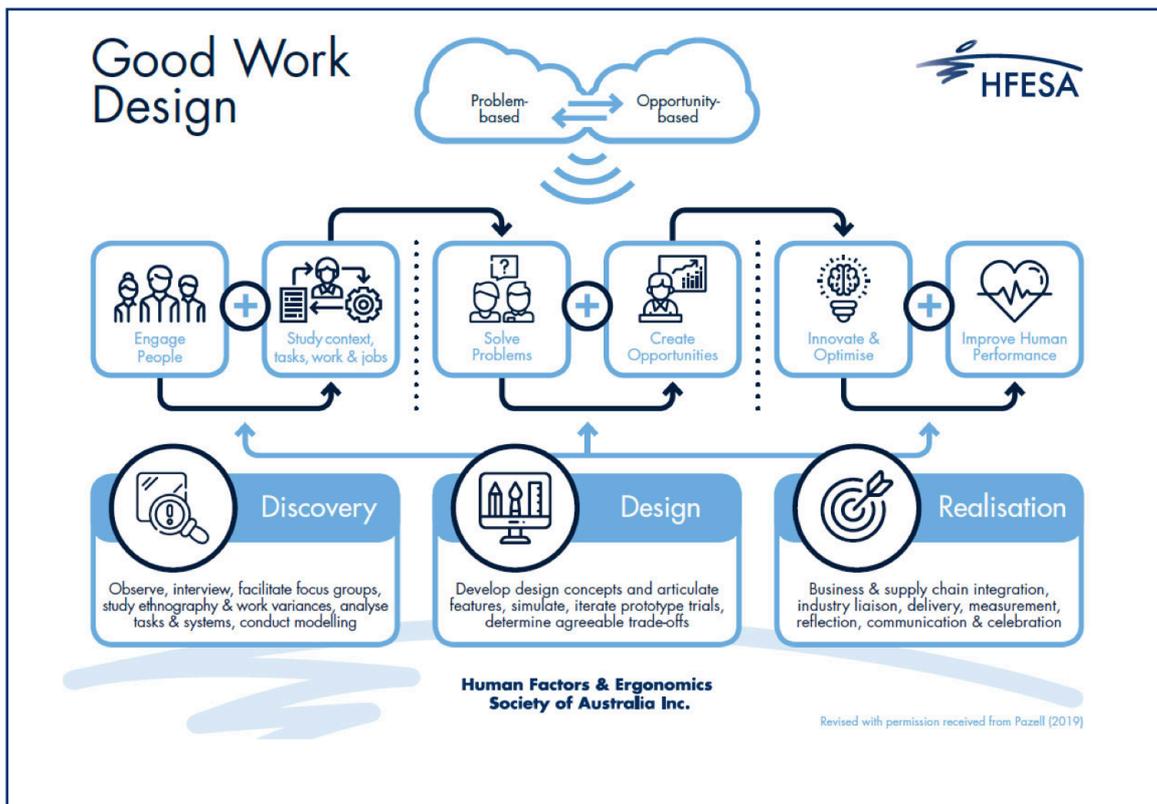


Figure 10: Good work design (HFESA, 2020b, p. 4) (Reproduced with permission of HFESA)

²⁷ See also OHS BoK 34.4 Design of Work (in development at time of writing).

7.1.3 Work environment

Design of the work environment can impact all domains of physical and psychosocial factors.

Physical environment

When designing workplaces, it is important that the design be as inclusive as possible at the outset as designing for a diverse population at the planning and building stage will reduce the need to make changes at a later date. The concept of 'universal design' is about designing buildings, environments, workplaces and products to make them as accessible to as many people as possible regardless of age, sex, disability or ability.²⁸ Universal design recognises that everyone is different. Examples include:

Environmental – effective lighting; adequate space for travel and maneuvering; minimal noise levels; elimination of obstacles in path of travel; accessible entrances.

Controls and Tools – accessible door handles, light switches, elevator controls, faucets; tools with textured grips with a diameter which minimizes grasping force.

Workstation and Storage – minimal glare; blinds or curtains on windows adjacent to workstation; adjustable chairs and workstations (ergonomic furniture); storage in range of reach for all employees; organizers and file folder storage on the desktop.

Computers – accessibility features in operating systems; training in the ergonomics of seating posture and positioning; ergonomic use of keyboard, mouse and monitor.

Communications – volume controls on telecommunication equipment; accessible, high contrast signage; alternate formats (large print, electronic files).

Safety – multi-sensory alarm signals (auditory, visual); emergency and safety equipment clearly identified and placed in a conspicuous location. (Northwest ADA Centre, 2017, p. 3)

It is necessary to understand how the design of a work environment – including structures, plant, equipment, tools and processes – will affect the health and safety of workers who interface with that environment. Also, it is important to consider how the life cycle of a work environment may change the nature of WMSD risk over time. There is an interrelationship between good workplace design and a risk-management approach (Figure 8), with hazard identification, risk assessment and risk control being key features. It is important that the risk-assessment process is applied to each phase of the design process.²⁹ Guidance in relation to workplace design and layout of work areas is available in the *Managing the Work Environment and Facilities Code of Practice* (SWA, 2018b). Addressing physical factors such as thermal environment, noise, vibration, underfoot conditions, lighting and air quality can reduce the risk of WMSDs.³⁰

²⁸ See, for example, universaldesignaustralia.net.au/

²⁹ A tool to support the involvement of OHS professionals at each stage in the design process is included in *OHS BoK 34.3 Health and Safety in Design*.

³⁰ See *OHS BoK 26 Thermal Environment*; *OHS BoK 22.1 Noise*; *OHS BoK 22.2 Vibration*; *OHS BoK 27 Gravitational Hazards*; *OHS BoK 17.2 Fibres, Dusts and Fumes* (in development at time of writing).

Psychosocial environment

Psychological factors in the work environment identified in Figure 5 (e.g. support, supervision, morale, perception of workplace culture/climate) may be considered under the 'organisational culture' umbrella. The *OHS Body of Knowledge* chapter 10.2.2 *Organisational Culture: Reviewed and Repositioned* concluded that OHS professionals planning culture-based interventions to improve OHS outcomes may be best served by focusing on:

...safety climate as a tool for measuring the effectiveness of interventions, developing organisational structures and practices for delivering successful interventions, and remembering all the while that safety climate and safety culture are but metaphors for understanding the same thing – how to create a healthy and safe working environment as the law requires (p. 23).

Because organisational climate and safety climate reflect 'perceptions' of organisational systems, it is imperative that the workers are integral to any design activity addressing the work environment and associated WMSD risk. The good work design process (Figure 10) also applies to the design of the work environment, with safety climate tools offering scope for measuring outcomes.

7.2 Substitution and engineering controls

With respect to physical hazards, in some cases safe and good design may enable hazardous tasks to be eliminated, but it is often not practical to eliminate all WMSD risk. Design can then be used to reduce the risk by substituting hazardous loads, movements, postures, workflows and work environment with less-hazardous options. Use of mechanical aids (powered and unpowered), is also an important method of reducing WMSD risk.³¹ The design, selection and implementation of mechanical aids should follow the good work design process (Figure 10) and be accompanied by a risk assessment to identify any hazards or unintended consequences associated with their introduction.

The *OHS Body of Knowledge* chapter 19 *Psychosocial Hazards* emphasises the importance of organisations focusing attention on primary or preventive strategies that optimise work resources and address work demands by targeting work design, work conditions, organisational communication and management of change. Secondary (ameliorating) and tertiary (reactive) interventions also have a place in supporting individuals experiencing strain from psychosocial hazards. Risk-control plans for psychosocial hazards should embrace the following:

- Activities to control the risk should be organisation and work-group specific, and adapted to the needs, cultures, politics and economic realities of the organisation/work group

³¹ For examples of mechanical aids, see SWA (2018a, pp. 36-41, 57-58).

- Activities to control the risk should be targeted to problem psychosocial hazards identified via risk assessment
- Risk-control plans should focus on primary prevention, but also include secondary and tertiary prevention activities
- Risk-control plans should focus on organisational-level interventions, but also include individual-level interventions
- A focus on worker training, including mental health training, or off-the-shelf risk-control interventions is unlikely to ensure health and safety.³²

7.3 Administrative controls

In addition to procedures and supervision, administrative controls for WMSDs focus on training for physical risk factors and management of factors that contribute to psychosocial stressors.

7.3.1 Training

Training as a control measure for WMSD risk has been a contentious issue for many years (Oakman et al., 2019). Although types of training offered include task-based, manual handling technique, and physical strength / work hardening, only task-based training has a recognised role in WMSD risk reduction. Manual handling technique training has been demonstrated to be ineffective, and strength training / work hardening is of limited use at best (HFESA, 2020c).

Task-based training

Workers must be provided with information, instruction and training for the tasks they are required to undertake in order to perform them safely (WHSA, s 19; SWA, 2019). Where hazardous manual tasks (HMT) are identified (section 6.1), training should be provided to assist workers and management to identify and understand HMTs, the risk factors that cause them, and the solutions that reduce the risk (HFESA, 2020a). If the hierarchy of control has been applied and there remains a residual risk, then task-based training may be required, noting that it does not address legal compliance and must not be used as the sole method of controlling WMSD risk. Augmented reality and virtual reality technology may prove valuable in task-related training.

Manual handling technique training³³

'Manual handling technique training' or 'lifting training' generally emphasises physical movements or postures such as *bend your knees and keep your back straight* without

³² OHS BoK 19 Psychosocial Hazards (p. 30). See also SafeWork NSW (2021).

³³ This section is informed by HFESA (2020a).

addressing the risk factors causing the problem. Such training is still common in many industries and is sometimes offered by training providers or consultants despite evidence that it is ineffective for WMSD risk control. For example:

- In 1971, Brown found that despite extensive information campaigns, very few workers used the 'straight back – bent knees' technique' (Hagberg et al., 1995).
- In 1978, Snook compared three approaches to low-back injury prevention – pre-employment selection, training in lifting techniques, and job design – and found no difference in the proportion of injuries in companies that did or did not train their workers in lifting technique (Bridger, 2018).
- Hogan et al. (2014) reviewed 13 investigations of the effectiveness of manual handling training and concluded that such training “does not always lead to the expected behavioural change” (p. 93).
- Verbeek et al. (2012) found “moderate quality evidence that [manual handling technique training] does not prevent back pain or back pain-related disability when compared to no intervention or alternative interventions” (p. 2).
- A review of the literature over the last 50 years (Bridger, 2018) found manual handling technique training to be ineffective as a risk control for WMSDs.

The clear message from the research is that manual handling technique training is not effective (Oakman et al., 2019) and that WMSD risk is determined by task design. Taught techniques are not necessarily safe, usable, risk-reducing, or transferable to work-as-done (Bridger, 2018).

Strength-based training

Strength-based, or work-hardening, programs can lead to improvements in a variety of fitness and health outcomes for both uninjured workers and injured workers undergoing rehabilitation and return-to-work programs. General exercise programs may help prevent WMSDs in jobs requiring a high level of muscle strength (Hagberg et al., 1995), however the results of intervention studies are inconsistent. While a strength-training program aimed to increase an individual's core strength, upper-body strength or strength-endurance of leg muscles may result in strength gain, there is no guarantee of injury prevention if the many factors influencing WMSD risk are not addressed. For example, if a worker is required to perform a task that requires twisting their trunk while they lift a load, their core strength may be insufficient to withstand the postural stress involved, irrespective of any strength gain as a result of training. If the task is performed while seated in a restricted space, the added mechanical stress may well exceed any strength training effect gained. Also, the effectiveness of any exercise-based intervention is dependent on the individual's adherence to the program, which is often a limiting factor.

Compared to general exercise programs, work-hardening programs are generally highly structured and goal-oriented, and often intended to condition a person for a specific job after a period of absence or injury. To be effective, a work-hardening program must:

- Be of greater intensity than that experienced on the job
- Be structured and graded and take a progressive approach
- Use exercises that closely resemble the movements made on the job
- Be evaluated using tests and simulate the activities carried out during training (Bridger, 2018).

If the program does not align with the tasks required, then it may be ineffective. Strength may be just one aspect of such a program, which could include other key components such as flexibility and endurance.

7.3.2 Other administrative controls

Other administrative controls may include job rotation and rest breaks, however there is little evidence indicating their effectiveness. It is generally accepted that switching between work tasks that use different muscle groups (job rotation) can reduce risk exposure. However, research in the textile industry (Comper et al., 2017) found job rotation to be ineffective in reducing both the prevalence of musculoskeletal symptoms and the number of work hours lost as a result of sick leave due to musculoskeletal pain. Comper et al. suggested that this was due to similarities in the work tasks that did not allow different muscle groups to be used and that the focus should be on good work design rather than job rotation. A different situation may exist where static postures or repetitive movements are a feature of the work. After design principles have been applied to eliminate the static postures or repetitive movement as far as reasonably practicable, it may be necessary to implement task variation.

Rest breaks at work have been suggested as a means of reducing WMSD risk in the workplace. However, a systematic review by Van Eerd et al. (2016) found only limited evidence supporting the effectiveness of rest breaks. This does not mean that rest breaks should not be provided for those involved in physical work. Conversely, for those involved in sedentary work, long periods spent sitting at computer terminals are linked with long-term health issues including WMSDs (Park et al., 2020), with such workers encouraged to build activity into their day (Burkhalter, 2019; SafeWork NSW, 2020).

7.4 Personal protective equipment

Jellema et al. (2001) and Verbeek et al. (2012) found no evidence to support use of manual handling assistive devices such as 'back belts' for preventing and treating back pain. Such devices should not be deployed as a method of WMSD risk control. Depending on the task, there may be a role for appropriate footwear, knee pads, aprons or gloves, noting that in some cases gloves may contribute to other risks (e.g. finger entrapment).

Increasingly, wearable technology (e.g. smart watches, smart clothing and movement sensors) is being used in organisational environments to evaluate physiological and biomechanical loading. Smart PPE provides real-time information about the thermal environment or the loads being applied to the body (Thierbach, 2020). Opinions of smart PPE sought during an OHS workshop in Germany were summarised to include the following:

- 'Less is more' with respect to presentation of data to the wearer; avoid information overload
- Wearers prefer to trigger the display of certain data themselves
- Wearers' data should not be collected and stored
- Functionality and acceptability should be tested by end users
- Equipment must be practical and ergonomic
- Care and maintenance of equipment must not entail substantial additional effort
- Wearers must be fully informed regarding the mode of operation, functions and limits of smart PPE (Thierbach, 2020).

Exoskeletons have been identified as a possible means of reducing exposure to physical hazards within the workplace (e.g. Nussbaum et al., 2019). Exoskeletons are generally grouped into active devices (those that use actuators) to give additional strength to the user, and passive devices (that use springs, dampers or other materials) to give support to the user (Peters & Wischniewski, 2019). While these devices have been used in medical environments for many years, there is limited evidence of the workplace impact of exoskeletons either on physical load reduction or physiological discomfort causation (Peters & Wischniewski, 2019). When assessing the value of exoskeletons in the work environment, the following aspects should be considered:

- Under specific conditions, exoskeletons can reduce muscle fatigue so may reduce injury
- The weight of the exoskeleton may impact cardiovascular demands
- Permanent support may impact individual muscle mass and reduce body strength
- Pressure points should be assessed to reduce the risk of pinch points or pressure on blood vessels caused by straps
- Materials should be evaluated to ensure they are not a source of skin irritation
- Use may result in a redistribution of load onto the spine and/or the legs
- Workers' perceptions of whether exoskeletons are usable, comfortable and socially acceptable are important (Peters & Wischniewski, 2019).

Also, emergency ingress and egress into exoskeletons (and the ability to remove them alone) needs to be evaluated to ensure all users can remove equipment and evacuate if required. It is recommended that cost-benefit evaluations be carried out to identify any alternative technical or organisational solutions to improve ergonomic design that may prove simpler or more cost-effective than exoskeletons (Schick, 2018; Reid, 2021).

7.5 Examples of interventions

With reference to the WMSD hierarchy of control (Figure 9), Table 9 provides examples of controls for four of the five categories of risk factors identified in Figure 5. The category of 'external factors' is excluded as these factors are largely beyond the control of the workplace.

Table 9: Examples of interventions to prevent WMSDs based on level of hierarchy of control and category of risk factor

WMSD hierarchy of control level	Workplace environment	Work organisation and job design ³⁴	Task and equipment	Workers
1: Elimination	Design/review work environment applying safe design principles and processes ³⁵		Procurement and purchasing policies to eliminate/minimise introduction of: <ul style="list-style-type: none"> • WMSD risk • Vibration hazard³⁶ Design/review task and equipment applying safe design principles and processes ³⁷	
2: Substitution, Engineering Controls	Minimise physical work environment stressors such as noise, heat and air quality ³⁸ Minimise psychosocial stressors in the work environment considering: ³⁹ <ul style="list-style-type: none"> • Co-worker and supervisor support • Recognition and reward processes • Change management 	Design work to reduce psychosocial stressors by addressing: <ul style="list-style-type: none"> • Physical, cognitive and emotional demands of job • Clarity of job roles and any conflict with other roles • Job control • Job security and promotion opportunities • Individual 	Design new work tasks and redesign existing work tasks to reduce biomechanical/postural stress by: <ul style="list-style-type: none"> • Minimising the reach distance to grasp or hold load • Eliminating the need to twist the trunk while supporting or lifting a load • Limiting the height at which an object is lifted or lowered to between knee and shoulders • Minimising the time 	

³⁴ See *OHS BoK* 34.4 Design of Work (in planning at time of writing).

³⁵ See *OHS BoK* 34.3 Health and Safety in Design.

³⁶ See *OHS BoK* 22.2 Vibration.

³⁷ See *OHS BoK* 34.3 Health and Safety in Design.

³⁸ See *OHS BoK* 22.1 Occupational Noise; *OHS BoK* 36 Thermal Environment; *OHS BoK* 17.2 Fibres, Dusts and Fumes (in development at time of writing).

³⁹ See *OHS BoK* 19 Psychosocial Hazards.

WMSD hierarchy of control level	Workplace environment	Work organisation and job design ³⁴	Task and equipment	Workers
	processes <ul style="list-style-type: none"> Organisational justice 	differences in coping style and work conditioning of workers <ul style="list-style-type: none"> Flexibility allowing for external work-home commitments and conflict 	to hold or carry loads <ul style="list-style-type: none"> Minimising the number of times to lift or carry loads Eliminating the need to lift objects while seated Minimising weight to be handled Minimising static work Using mechanical aids and powered plant 	
3: Administrative Controls		Design work to reduce psychosocial stressors by addressing: <ul style="list-style-type: none"> Time pressure and deadlines Hours of work, rest breaks and workload Work schedules and flexibility, predictability and sociability of work hours Training in how to set up a workstation Elimination of remuneration based on piece work 	<ul style="list-style-type: none"> Task rotation Worker participation in decision making and control over workload and work pace Workers' capacities and skill levels matched to tasks Time available for task Training in use of equipment Maintenance of equipment 	<ul style="list-style-type: none"> Fatigue management strategies⁴⁰ Task-specific training
4: Personal Protective Equipment			<ul style="list-style-type: none"> PPE appropriate to the task (e.g. footwear, kneepads, aprons, gloves) Wearables Exoskeletons 	

⁴⁰ See OHS BoK 20 Fatigue.

7.6 Implementation

This chapter has emphasised the multifactorial causation of WMSDs and the need for a multifaceted approach to their management. The development of a WMSD risk-management program should be an integral part of a comprehensive organisational systems approach to OHS risk management⁴¹ that considers the interaction of hazards rather than each hazard in isolation. Key to successful implementation of such an approach are:

- Commitment by supervisors, managers and other decision makers
- Participation of workers in hazard identification, assessment processes and development of risk controls.

7.6.1 Commitment of decision makers

The commitment of managers and supervisors to WMSD management is vital as their decisions, and often their behaviours, may be sources of WMSDs and psychosocial hazards (Oakman et al., 2016). Also, their commitment is essential for resourcing and achieving organisational change. Decision makers require training to ensure their understanding of:

- Their role in management of WMSDs
- The impact of WMSDs on workers and their ability to work
- The complexity of causation and management of WMSDs
- How to reduce organisational silos so that information is shared between managers, human resources and OHS
- The importance of participation by workers in the risk-assessment process
- The value of open communication between senior management and the workforce (Crawford & Davis, 2020).

7.6.2 Participatory approaches

Consultation with, and participation of, workers is essential in the design and development of interventions for WMSDs. Persons in control of a business or undertaking are required to consult with workers

- (a) when identifying hazards and assessing risks to health and safety arising from the work carried out or to be carried out by the business or undertaking;
- (b) when making decisions about ways to eliminate or minimise those risks; ...
- (d) when proposing changes that may affect the health or safety of workers; ... (WHS Act, s 49; SWA, 2019, pp. 45-46).

⁴¹ For an outline of the concept of systems and the application of systems thinking in OHS, see *OHS BoK 12.1 Systems and Systems Thinking* (in development at time of writing).

After interviewing regulators, industry association representatives and OHS professionals, Oakman et al. (2019) determined that worker participation in the design and implementation of interventions for WMSDs is essential for success. Such participation goes beyond the consultation required under the *Work Health and Safety Regulations* (SWA, 2021b). It is important to recognise that workers can provide valuable insights into the tasks they perform; they have intimate knowledge of the hazards and risk factors and how they, as workers, interact with the hazards and risks. This is particularly important with regard to WMSDs because some of the risk factors may be hard to identify, quantify and change (e.g. worker behaviours and personal characteristics). Participatory processes support inclusive work conditions to ensure matching of task demands with the physical and psychological capabilities of workers across gender, age, ethnicity and (dis)ability (Buckle, 2021). With awareness of potential differences between work-as-imagined and work-as-done, workers can provide valuable perspectives on the 'user-friendliness' and unintended consequences of proposed interventions to optimise acceptance and uptake (HFESA, 2020b).

Noro and Imada (1991) stressed that the complexity of the human-machine-environment working relationship necessitates input from a range of people, including experts and non-experts. The European Agency for Safety and Health at Work (Buckle, 2021) supported this broad view of participation, recommending that those involved should include representatives of the four main stakeholder groups of system design identified by Dul et al. (2012):

- 'System actors', i.e. employees, product/service users, who are part of the system and who are directly or indirectly affected by its design and who, directly or indirectly, affect its performance.
- 'System experts', i.e. professionals such as engineers and psychologists [and OHS professionals and ergonomists] who contribute to the design of the system based on their specific professional backgrounds. ...
- 'System decision makers', i.e. decision makers (e.g. managers) about the (requirements for) the system design, the purchasing of the system, its implementation and its use.
- 'System influencers', i.e. media, governments, standardisation organisations, regulators, citizens who have general public interest in work system and product/service system design. (Dul et al., 2012, p. 383)

The term 'participatory ergonomics,' first proposed in the early 1980s, is often used to describe such approaches. Based on the outcomes of reviews conducted between 2004 and 2016, Burgess-Limerick (2018) described evidence for the impact of participatory ergonomics on prevalence of WMSDs as 'mixed.' However, interpretation of the results of this work is complicated by the diversity of interventions that come under the 'participatory ergonomics' umbrella. Importantly, organisations most likely to implement successful participatory ergonomics programs:

- are less hierarchical
- have good labour relations
- [have] a tradition of consultatory processes in other areas
- [have] good communication channels
- [have] job design which emphasises personal control. ...

[Other supportive factors include:]

- commitment of management, at all levels ... to ensure adequate resources are available ...
- middle managers within the organisation maintain commitment in the face of inevitable production pressures ...
- genuine participation by team members ...
- presence of a site champion ...
- expert facilitation (Burgess-Limerick, 2018, pp. 289, 291).

Effective consultation and worker participation in decision making takes time and skill on behalf of the facilitator and participating workers. Participative processes can be used to develop workers' knowledge of practical aspects of ergonomics and their application.

Effective participation also requires that workers:

...acknowledge the need for participation...trust that their participation will not have negative effects...perceive that changes are being introduced in a legitimate way...believe that change is being implemented correctly...[and] be given a real role to play in the introduction and testing of new ways of working” (Bernoux as cited in Bridger, 2018, p. 13).

There must be time allocated early in the planning process for worker engagement to avoid early-stage decisions that cannot be reversed by the people who make the system work. Participative approaches are more likely to generate positive outcomes and be more cost-effective than retrofitting or a worker suffering a WMSD as a result of a mismatch with the task or work environment.

8 Implications for OHS practice

This chapter provides evidence that supports taking a holistic and participatory approach to understanding and managing WMSDs; this goes beyond the physical aspects of the task and reliance on ineffective manual handling technique training. It presents an ergonomics systems model (Figure 5) with five categories of WMSD causation factors:

- External
- Physical and psychological workplace environment
- Work organisation and job design
 - Job demands
 - Psychosocial hazards
- Task and equipment
- Worker.⁴²

⁴² Case studies demonstrating the application of this model are provided on the *OHS BoK* webpage for this chapter under *Resources*.

This holistic approach requires generalist OHS professionals to take on a facilitation role informed by their knowledge of WMSD multifactorial causation. Such facilitation may include:

- Engaging with and 'educating' managers, supervisors and others who impact the design of work and tasks (e.g. engineers, procurement and human resources) on the multifactorial causation of WMSDs, especially the impact of psychosocial hazards
- Advocating for, and supporting worker involvement in, hazard identification and risk assessment
- Ensuring worker input early in the design or redesign of work, tasks, equipment or work environment⁴³
- Ensuring appropriate specialist input to the design or redesign of work, tasks, equipment or the work environment, and facilitating the engagement of such specialists with workers to ensure that the specialists have a full understanding of the work, tasks, equipment and the work environment.

As with all OHS change-management processes, advocacy and facilitation of change will face barriers. These may include:

- Lack of prioritisation of time/resources by operational and management personnel
- Lack of communication among individuals and across organisations
- Lack of management support, commitment and participation
- Lack of knowledge about causation, level of risk, long-term health effects and strategies for control
- Resistance to change at both worker and management levels
- Lack of trust, fear of job loss or loss of authority (Yazdani & Wells, 2018).

In taking up this advocacy and facilitation role, the OHS professional may be challenged to change an existing organisational mindset focused on risk-reduction measures that have little supporting evidence of effectiveness. The presence of such mindsets was clearly identified in the European Agency for Safety and Health at Work report (Crawford et al., 2020) that found that not all organisations carry out risk assessment for WMSD risks and, when they do, risk-reduction measures tend to focus on strategies with little supporting evidence of effectiveness. Achieving such a change may be complicated by variations in approach to WMSDs by those working in OHS and allied areas, detracting from any unified consensus on the prevention and management of WMSDs. As the first point of contact for professional advice on the management of WMSDs, generalist OHS professionals should be able to present research evidence as outlined in this chapter to advocate for and support a holistic, participative approach to the management of WMSDs. This process is summarised in Figure 11.

⁴³ See *OHS BoK* 34.3 Health and Safety in Design.

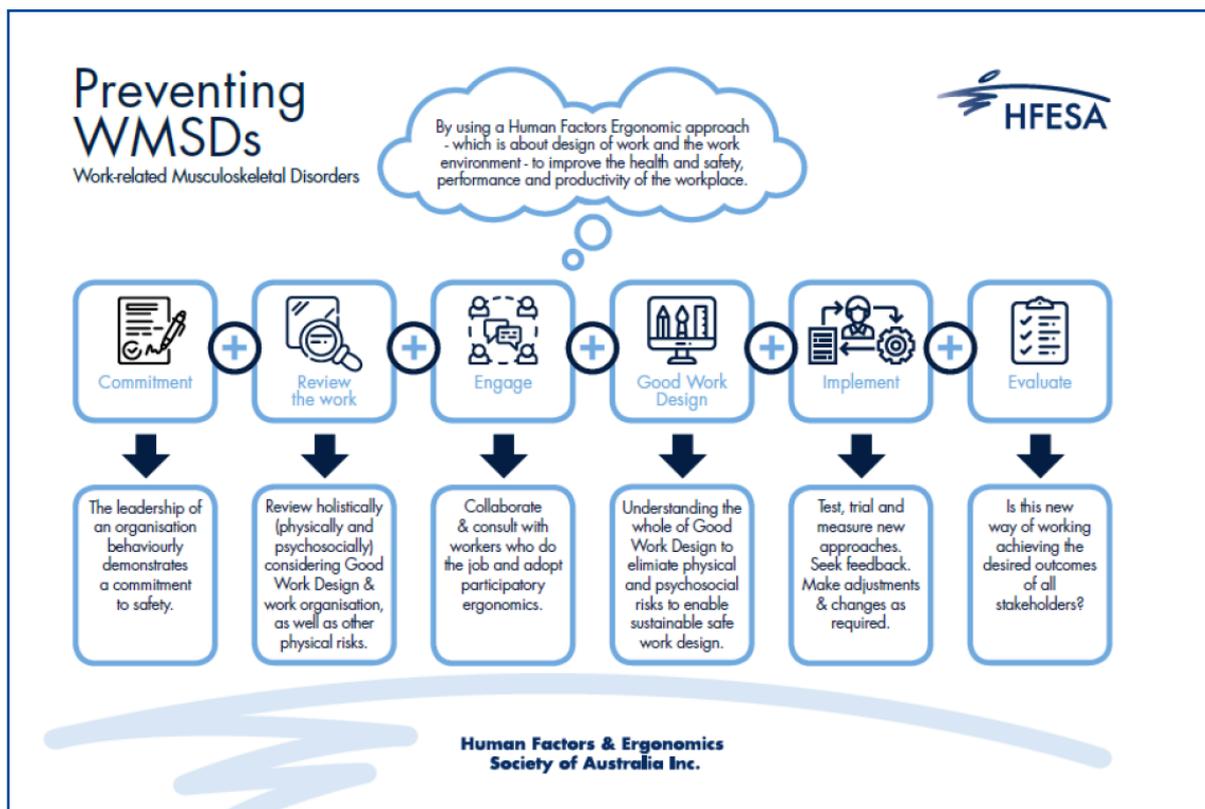


Figure 11: HFESA position on the steps and process required to prevent WMSDs (HFESA, 2020a, p. 20) (Reproduced with permission of HFESA)

As “a key advisor, strategist and pilot to the organization’s leadership in fully integrating the management of OHS risk into sustainable business practice at all levels” (INSHPO, 2017, p. 10), the generalist OHS professional has a primary role in advising on the prevention and management of WMSDs. This role includes the development of holistic WMSD prevention strategies and facilitation of implementation plans that integrate with the existing management structure, consider operational realities and address the barriers to success. Part of this primary role may require seeking the input of specialist advisors. The need for a specialist advisor may be indicated by a risk assessment that identifies:

- Significant complexity of the work
- Organisational factors and/or environment impacting WMSD risk that require the objective analysis and counsel of an external advisor
- The need for significant design change.

It is likely that an ergonomist will be the specialist advisor most likely to be engaged by a generalist OHS professional in relation to WMSDs. As defined by HFESA (2020b):

Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance.

Practitioners of ergonomics and ergonomists contribute to the design and evaluation of tasks, jobs, products, environments and systems in order to make them compatible with the needs, abilities and limitations of people.

In seeking the advice of an ergonomist, Australian-based OHS professionals should note that Certified Professional Ergonomists (CPE) have undergone assessment by HFESA of knowledge, practice and experience and are committed to continuing professional development.⁴⁴ Also, the International Ergonomics Association (IEA) has endorsed a number of country-specific certification bodies for professional ergonomists (including HFESA's CPEs and the Human Factors and Ergonomics Society of New Zealand's Certified Professional Members).⁴⁵

9 Summary

This chapter identifies WMSDs as a priority workplace condition responsible for more than a third of all Australian workers' compensation claims in 2018-19, with this proportion known to be an underrepresentation of WMSD prevalence.

Although the impact of work on musculoskeletal structures has been acknowledged since early times, a physical approach largely focused on weight limits and manual handling technique prevailed until the RSI epidemic of the 1980s exposed the complexity of WMSDs. Research during the last 20 years has improved our understanding of the causation of WMSDs, including the role of psychosocial hazards. There has been limited transfer of the research findings to the workplace the continuing focus on a primarily physical model of causation. With OHS practice informed by this chapter, there is potential for this situation to change a more holistic approach.

WMSDs may arise from a single traumatic incident or cumulative microtrauma. This cumulative pathophysiology adds to the complexity of WMSDs as risk factors are likely to have been present for some time before the onset of symptoms and well before diagnosis of an injury.

⁴⁴ There are three domains of specialisation within ergonomics – physical, cognitive and organisational (HFESA, 2020c). To locate a CPE, see www.ergonomics.org.au/find-a-cpe

⁴⁵ See IEA Endorsed and Recognised Certification Systems for Professional Ergonomists at iea.cc/iea-recognized-and-endorsed-certification-systems-for-professional-ergonomists/

A holistic approach to understanding causation and preventing and managing WMSDs is recommended. A multifactorial model with examples of workplace factors that influence WMSD risk is presented (Figure 5). This model, which addresses physical and psychosocial factors, should be a reference point for the identification and assessment of WMSD risk and development of controls. A hierarchy of control specific to WMSDs is outlined (Figure 9). The importance of the commitment and participation of decision makers and the involvement of workers in hazard identification and risk assessment and the design and implementation of controls is emphasised.

Generalist OHS professionals have a primary role in the prevention and management of WMSDs. They should be advocating for a holistic, participative approach that addresses both physical and psychosocial risk factors. This may require a change of mindset within the organisation and achieving such a change will require the OHS professional to be familiar with the supporting evidence.

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Appendix 1: Hazard-identification/risk-assessment tools for WMSDs

The table below provides a list of risk-assessment methods and tools for categories of WMSD risk factors identified in Figure 5. Many of the entries are drawn from Oakman et al. (2019, pp. 33-34). Although some of these tools require specialist knowledge of ergonomics, generalist OHS professionals should be familiar with their appropriate application.

Method	Summary of hazards assessed	Reference/link
TASK AND EQUIPMENT		
Assessment of loads and postures		
Ovako Working Posture Analysing System (OWAS)	Defines body postures during working practice and scores them according to strain caused (Scott & Lambe, 1996)	Karhu et al. (1977, 1981)
Revised Strain Index (RSI)	A hand/arm physical exposure assessment model based on intensity, frequency and duration of exertion, and hand/wrist posture	Garg et al. (2017)
Rapid Upper Limb Assessment (RULA)	A tool for assessing risk related to upper-body postures	McAtamney & Corlett (1993)
Rapid Entire Body Assessment (REBA)	A postural-analysis tool that extends RULA to the whole body	Hignett & McAtamney (2000)
Liberty Mutual Manual Materials Handling tables	Tables that specify acceptable load limits based on a range of task parameters	Snook (1978); Potvin et al. (2021) https://libertymmhtables.libertymutual.com/
3D Static Strength Prediction Program™ (3D SSPP)	Software that predicts static strength requirements for tasks such as lifts, presses, pushes and pulls	https://www.ehs.com/solutions/ergonomics/3d-sspp/
Assessment of repetition		
Occupational Repetitive Actions (OCRA)	Assessment based on a recommended number of reference technical actions; the number is derived from a product of multipliers describing repetitiveness of task postures of the upper limbs, exerted forces and cycle times; considers movement of the forearm (Oakman et al., 2019)	Occhipinti (1998); Colombini & Occhipinti (2018)
ACGIH TLV for hand activity (HAL)	Assessment of hand activity and level of effort on a 0-10 scale for a typical posture while performing a short-cycle task	Latko et al. (1997) https://health.usf.edu/publichealth/tbernard/~media/096358E538

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NIOSH Lifting Equation (Revised)	Allows calculation of a recommended weight limit (RWL) and lifting index (ratio of the load lifted to the RWL) for manual lifting tasks	Lu et al. (2016); NIOSH (1981) https://www.cdc.gov/niosh/topics/ergonomics/nlecalc.html
HSE Assessment of Repetitive Tasks (ART)	A tool designed to help identify, assess and reduce risks associated with repetitive tasks involving the upper limbs	https://www.hse.gov.uk/msd/uld/art/index.htm
Assessment of a wider range of physical hazards		
Manual Tasks Risk Assessment (ManTRA)	A tool that applies ratings to manual task characteristics (cycle time, repetition, force, speed, awkwardness and vibration) and calculates repetition, exertion and cumulative risk scores for body regions	https://fswqap.worksafe.qld.gov.au/etools/etool/mantra/#step1
Participative Ergonomics for Manual Tasks (PErforM)	A participative ergonomics risk-management program that provides a framework for identifying and controlling manual tasks	https://www.worksafe.qld.gov.au/safety-and-prevention/hazards/hazardous-manual-tasks/participative-ergonomics-for-manual-tasks-perform/perform-resources
HSE Assessment of Pushing and Pulling (RAPP)	A simple tool designed to help assess the key risks in manual pushing and pulling operations involving whole-body effort	https://www.hse.gov.uk/msd/pushpull/index.htm
HSE Manual Handling Assessment Charts (MAC)	A tool to assist identification of high-risk manual handling activities as an addition to the risk-assessment process	https://www.hse.gov.uk/msd/mac/index.htm
A Participation Hazard Identification and Risk Management (APHIRM) toolkit	A set of risk-management procedures for evaluation of physical and psychosocial risks and prioritisation of actions	https://www.aphirm.org.au/
WORK ORGANISATION AND JOB DESIGN		
Assessment of Job Demands		
Nordic Musculoskeletal Questionnaire	Standardised survey questionnaires for analysis of musculoskeletal symptoms, allowing comparison of low back, neck, shoulder and general complaints for use in epidemiological studies	Kuorinka et al. (1987)
HSE Fatigue and Risk Index Calculator	A calculator with two indices, one relating to fatigue and one relating to risk	https://www.hse.gov.uk/research/rrpdf/rr446g.pdf

Psychosocial hazards		
Australian Workplace Barometer (AWB)	Assessment of psychosocial safety climate (PSC) via a 12-item scale	Dollard et al. (2012)
People at Work (PAW)	A psychosocial risk-assessment tool with benchmarking; also provides detailed information and practical tips and templates to support workplaces through a 5-step process	https://www.worksafe.qld.gov.au/safety-and-prevention/mental-health/people-at-work
Publicly Available Specification (PAS) 1010:2011	<i>Guidance on the Management of Psychosocial Risks in the Workplace</i> provides practical guidance on the policies and key principles involved in the management of psychosocial risks in work environments and how organisations can help tackle these issues	http://www.prima-ef.org/pas1010.html
Copenhagen Psychosocial Questionnaire (COPSOQ)	Validated in several countries, COPSOQ domains include demands at work, work organisation and job contents, interpersonal relations and leadership, work-individual interface, social capital, offensive behaviours, health and wellbeing	Burr et al. (2019) https://www.copsoq-network.org/
Job Content Questionnaire (JCQ)	Based on the Demand-Control-Support model, the JCQ assesses psychosocial hazards for stress-related health problems; rarely applied to assessment of WMSD hazards	https://www.jcqcenter.com/questionnaires-jcq-jcq2/
Work Organisation Assessment Questionnaire (WOAQ)	Developed as part of a risk assessment/reduction methodology for manufacturing, the WOAQ has since been validated for use in other sectors	Griffiths et al. (2006)
HSE Management Standards	A systematic approach to implementing an organisational procedure for managing work-related stress	https://www.hse.gov.uk/pubns/wbk01.htm
WORKPLACE ENVIRONMENTAL FACTORS		
Assessment of physical factors		
SafeWork NSW Maintaining Thermal Comfort in Indoor Work Environments	Guidance on risk assessment for the thermal environment	https://www.safework.nsw.gov.au/resource-library/heat-and-environment/maintaining-thermal-comfort-in-indoor-work-environments
Basic Thermal Risk Assessment	A qualitative assessment developed for use by frontline workers to increase understanding of the mechanisms and impacts of thermal assessments	Di Corleto et al. (2013); <i>OHS BoK 26 Thermal Environment</i>

Managing the Work Environment and Facilities Code of Practice	Approved code of practice on all aspects of the work environment	SWA (2018)
Psychological factors		
A Workplace Health and Wellbeing Toolkit	Guidance for workplaces developing their own health and wellbeing programs	SA Health (2014)

Appendix 1 References

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