Issues associated with force and weight limits and associated threshold limit values in the physical handling work environment

Robin Burgess-Limerick PhD CPE

UniQuest Pty Ltd

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Contents

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Executive Summary

Injuries occur when loads on anatomical structures are, either instantly or over time, greater than the structures can withstand. Anatomical complexity, individual variability in tissue tolerances, and the interactions between biomechanical, environmental, and psychosocial risk factors make the determination of valid threshold limit values for exposure to biomechanical risk factors exceptionally difficult. Consequently, it is recommended that:

1. *quantitative threshold limit values for weight, force, or other risk factors should not be provided within manual tasks regulation or advisory materials.*

A satisfactory risk assessment may be carried out in some situations without the use of any formal tool. However, given the difficulty of assessing injury risks associated with some manual tasks, better guidance is required than the "yes/no" checklists currently provided in advisory materials. While such checklists may be appropriate for risk identification, a more detailed tool is required to assist with risk assessment. It is recommended that:

2. *advisory materials related to manual tasks injury prevention should include an optional risk assessment tool which:*

   a) is applicable to the complete range of manual tasks
   b) provides an integrated assessment of biomechanical risk factors
   c) provides an independent assessment of injury risk to different body regions
   d) provides an overall risk assessment which allows prioritisation of tasks and incorporates guidance regarding thresholds for action, but does not imply misleading level of precision
   e) facilitates effective targeting of controls by providing an indication of the relative severity of different risk factors within a task
   f) is suitable for use by workplace staff with minimal training and equipment

The suitability of currently available tools is assessed against these criteria. The Manual Tasks Risk Assessment tool (ManTRA) best meets the above criteria, with the exception of the extent of training required in its use. It is recommended that:

3. *a simplified version of ManTRA should be provided within advisory documents to assist manual task risk assessment*

Ideally, manual task risk assessment and control should be performed by workplace teams including employees who perform the tasks being assessed, as well as staff responsible for managing manual tasks risk at the workplace. Consequently:

4. *appropriate training materials should be developed to support manual task risk management by employees and management.*

Preamble

This paper presents and discusses issues related to the stipulation of threshold limit values in legislation, and related advisory documents, which aim to reduce the prevalence of occupational injuries caused by exposure to manual handling. A broad definition of manual handling is utilised (consistent with current Victorian and Queensland advisory documents), and the more general term “manual tasks” is preferred to emphasise the broader scope; encompassing, for example, tasks involving repetitive movements of the upper limbs in addition to the handling of loads. The definition of manual tasks provided in the Queensland Manual Tasks Advisory Standard will be adopted:

> “Manual tasks are those workplace activities requiring the use of force exerted by a person to grasp, manipulate, strike, throw, carry, move (lift, lower, push, pull), hold or restrain an object, load or body part” [1] .

Whilst many injuries occur as a result of slips, trips, and falls which occur whilst undertaking manual tasks, such injuries will not be considered here. The assessment of the risks of falls should be considered independently of the musculoskeletal injury risks associated with manual tasks *per se*.

In seeking to provide regulation and guidance for the prevention of injuries which arise as a consequence of exposure to manual tasks, there is considerable attraction in providing quantitative threshold limit values for the relevant risk factors. Historically, limits were placed on the weight of loads to be handled. Such a simplistic approach fell out of favour as it became appreciated that weight was only one factor which contributed to the risk of injury. A range of tools have been developed more recently which provide assistance with manual task risk assessment, and could potentially be utilised to provide quantitative threshold values.

The aim of this paper is to examine the issues relating to the provision of threshold limit values for the range of risk factors associated with manual tasks. The paper will first summarise the knowledge base upon which threshold values might be determined. The approaches to the use of threshold values currently taken by selected national and international jurisdictions will be presented, and a range of tools which might be used to assess threshold values will be assessed. It is concluded that reference to Threshold Limit Values within regulation and advisory documents cannot be justified, but that an effective risk assessment tool should be provided. Criteria for such a tool are proposed, and candidate tools assessed against these criteria. A simplified version of a tool currently in use by Queensland workplace health and safety inspectors is recommended for use in manual tasks advisory documents

[1] DWHS (1999) *Manual Tasks Advisory Standard 2000*. Department of Industrial Relations, Queensland. (www.whs.qld.gov.au/advisory/adv028.pdf) p.6

Injury mechanisms

Injuries occur when loads on anatomical structures are, either instantly or over time, greater than the structures can withstand. The general problem with assessing the risks posed by manual tasks, and hence in setting threshold limit values, is that both the loads on structures (especially over time) and the capabilities of structures are difficult to estimate. Biomechanical models are used to estimate loads on anatomical structures, and mechanical testing of cadaveric specimens is used to estimate capabilities. Epidemiological data is used to infer the links by assessing the relationship between tasks and subsequent injuries. Psychophysical data has also been used to provide additional information about subjectively acceptable threshold limits.

Considerable attention has been paid to the epidemiological evidence for associations between various possible risk factors[2,3]. There is general agreement that evidence exists for a relationship between musculoskeletal disorders and prolonged exposure to forceful exertions, awkward and static postures, vibration, and repetition. Injuries are particularly associated with exposure to multiple risk factors. The strongest epidemiological associations for individual risk factors occur for vibration and forceful exertions.

Tissues at risk of damage due to manual tasks include bone, muscle, tendon, ligament, articular cartilage and other connective tissues, nerves and blood vessels. The mechanisms of injury to specific tissues are varied however, in general, injuries associated with manual tasks may be characterised as either acute or cumulative[4]. Acute injuries are associated with a relatively short exposure to loads which exceed the tissue tolerance. Cumulative injuries, as the term suggest, occur as a consequence of relatively long term exposure to loads. In the latter case, the general mechanism of injury is believed to be an accumulation of microdamage which exceeds the tissue's capacity for repair. Injuries may also occur as a combination of both general mechanisms where a history of cumulative loading leads to reduced tissue tolerance, which is then exceeded by short term exposure to a relatively high intensity load[5]. Appendix A provides more details regarding the mechanisms by which injury to different tissues occurs.

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[2] NIOSH (1997) *Musculoskeletal Disorders and Workplace Factors: A Critical Review of Epidemiologic Evidence for Work-Related Musculoskeletal Disorders of the Neck, Upper Extremity, and Low Back*. US Department of Health and Human Services. Publication No. 97-141

[3] NRC (1999) *Work-related musculoskeletal disorders*. Washington: National Academy Press.

[4] Kumar, S. (1999) Selected theories of musculoskeletal injury causation. In Kumar, S. (Ed.). *Biomechanics in Ergonomics.* London: Taylor & Francis. (pp. 3-24).

[5] McGill, S.M. (1997) The biomechanics of low back injury: Implications on current practice in industry and the clinic. *Journal of Biomechanics*, *30*, 465-475.

Evidence for threshold limit values

Back

More attention has been paid to determining threshold limits for preventing back injury than any other region. These approaches predominantly focus on the compressive forces applied to the lumbar spine, comparing estimates of spinal compression based on biomechanical models of varying complexity with estimates of tissue tolerance obtained from cadaveric data. The general problems with this approach are: a) tissue tolerances vary with age and sex, and load history; b) compression is only one contributing factor; c) accurate estimates of tissue load require complex measurement techniques; and d) exposure to whole body vibration interacts with other risk factors.

The most influential documents providing threshold values for manual lifting have been those prepared by NIOSH[6,7] which provided equations for assessing lifting tasks based on a threshold value of 3.4 kN for spinal compression. The NIOSH equation has been criticised in many respects[8,9,10,11,12] including Jager & Luttmann's[13,14,15] revelation that the 3.4 kN threshold value was not justifiable by the data from the 27 specimens from which the value was derived. Although 3.4 kN is within the range of values at which isolated lumbar vertebral bodies fail in compression, the range of variability is evident in the distribution of failure values compiled by Jager and Luttman from 776 specimens (Figure 1).

Jager et al's data also demonstrate that the compressive tolerance of the lumbar spine varies considerably as a function of sex and age (see Figure 2) and Jager et al present age and sex specific recommendations for acceptable lumbar compression (the "Dortmund" recommendations) which range from 6 kN for 20 year old males, to 1.8 kN for females older than 60 years (Figure 3). These data demonstrate that the NIOSH 3.4 kN threshold is not protective of older workers.

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6 NIOSH (1981) *Work practices guide for manual lifting*. NIOSH Technical report 81-122. Cincinnati: US Department of Health and Human Services.

7 Waters, T.R., Putz-Anderson, V., Garg, A., & Fine, L.J. (1993). Revised NIOSH equation for the design and evaluation of manual lifting tasks. *Ergonomics*, *36*, 749-776.

8 Dempsey, P.G., & Fathallah, F.A. (1999) Application issues and theoretical concerns regarding the 1991 NIOSH equation asymmetry multiplier. *International Journal of Industrial Ergonomics*, *23*, 181-191.

9 Dempsey, P.G. (1998) A critical review of biomechanical, epidemiological, physiological and psychological criteria for designing manual materials handling tasks. *Ergonomics*, *41*, 73-88.

10 Dempsey, P.G. (2002) Usability of the revised NIOSH equation. Ergonomics, 45, 817-828.

11 Lavender, S.A., Andersson, G.B.J., Schipplein, O.D., & Fuentes, H.J. (2003). The effects of initial lifting height, load magnitude, and lifting speed on the peak dynamic L5/S1 moments. *International Journal of Industrial Ergonomics*, *31*, 51-59.

12 Leamon, T.B. (1994) Research to reality: a critical review of the validity of various criteria for the prevention of occupationally induced low back pain. *Ergonomics*, *37*, 1959-1974.

13 Jäger, M.& Luttmann, A. (1997) Assessment of low-back load during manual materials handling. In: P. Seppälä, T. Luopajärvi, C.-H. Nygård, M. Mattila (Eds.): Musculoskeletal Disorders, Rehabilitation - Proceedings of the 13th Triennial Congress of the International Ergonomics Association, Vol. 4, pp. 171-173.

14 Jäger, M., & Luttmann, A. (1999). Critical survey on the biomechanical criterion in th NIOSH method for the deign and evaluation of manual tasks. *International Journal of Industrial Ergonomics*, *23*, 331-337.

15 Jäger, M.(1996). Biomechanical aspects concerning the assessment of lumbar load during heavy work and uncomfortable postures with special emphasis to the justification of NIOSH's biomechanical criterion. In: Bundesanstalt für Arbeitsmedizin, Berlin (Ed.) *Problems and Progress in Assessing Physical Load and Musculoskeletal Disorders*, Tagungsbericht 10. Wirtschaftverlag NW, Bremerhaven. (p. 49-72).

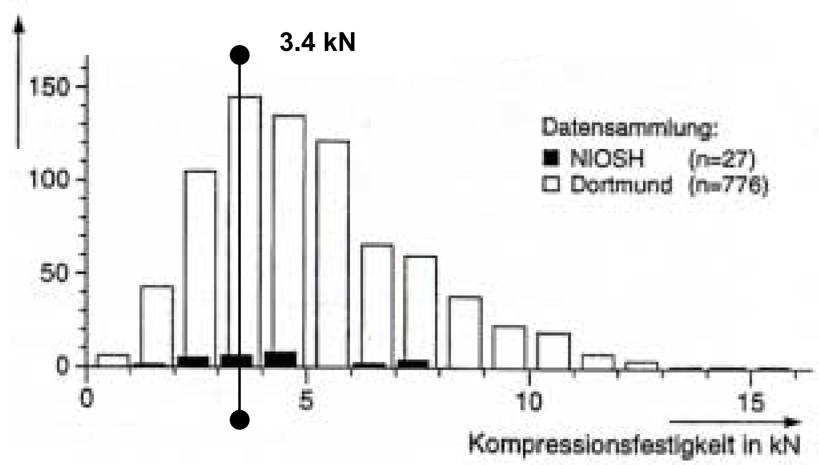

Figure 1: Distribution of lumbar vertebral body compressive strength[16]

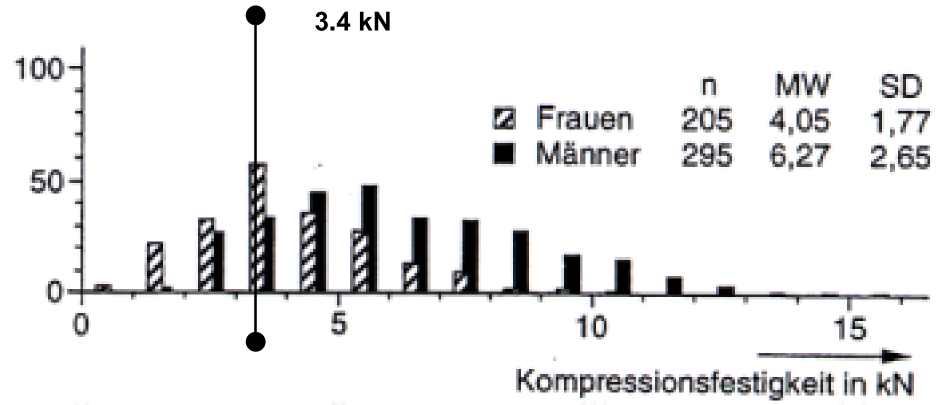

Figure 2: Compressive strength of lumbar vertebral bodies by sex[17,]

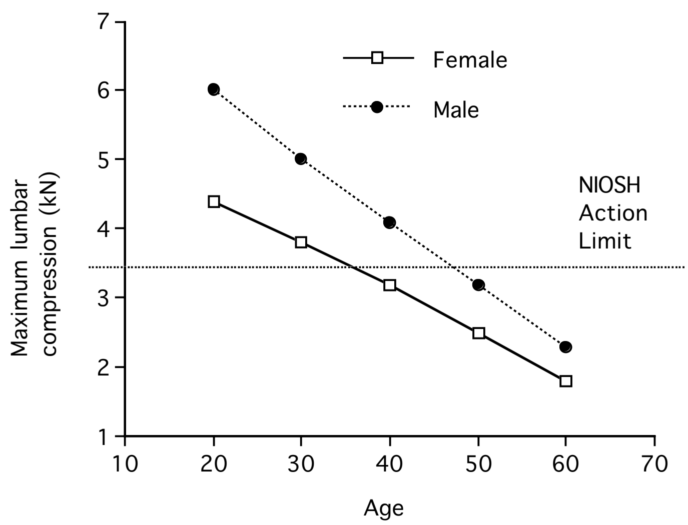

Figure 3: The "Dortmund" recommendations for maximum compressive strength as a function of age and sex[18]

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[16] Jäger, M., Luttmann, A., & Göllner, R.(2001) Belastbarkeit der Lendenwirbelsäule beim Handhaben von Lasten - Ableitung der „Dortmunder Richtwerte" auf Basis der lumbalen Kompressionsfestigkeit. *Zentralblatt für Arbeitsmedizin, Arbeitsschutz und Ergonomie, 51,* 354-372. in German with English abstract

[17] Jäger, M., Luttmann, A., & Göllner, R.(2001)

Even if the lumbar compressive forces experienced during a task could be accurately and practically be estimated under field conditions, and even if an appropriate threshold (or thresholds) for compression could be determined, lumbar compression is only one mechanism by which back injury may occur. There is little evidence to justify the reliance on compression alone as a predictor of back injury[19,20,21,22]. The importance of this statement is evident when other potential contributions to back injury are considered.

Compression combined with forward bending can cause anterior wedge fractures, and fractures of the pars interarticularis can be caused by shear forces (forces perpendicular to compression which tend to cause sliding of adjacent vertebral bodies). Such fractures may be acute, caused by high compressive forces applied during hyperextension (bending backwards), or cumulative as a consequence of prolonged exposure to repetitive flexion and extension movements under compressive load. Axial rotation (twisting) or hyperextension may cause damage to apophyseal joints[23]. Little is known about tissue tolerances in shear and torsion. The consequence of any individual load is also dependent on the history of loads applied to the structures.

Intervertebral discs provide flexibility to the spine and transfer forces between adjacent vertebral bodies. The discs are comprised of a central nucleus pulposus surrounded by an annulus fibrosus comprised of layers of fibrous tissues of varying orientations. Damage to the intervertebral discs does not occur as a consequence of compressive forces alone, even if the forces are applied repetitively, nor does twisting alone damage the disc[24]. Posterior disc prolapse may occur as a consequence of prolonged repetitive exposure to compressive force with the spine in a posture of full flexion. This is most likely to occur in relatively young intervertebral discs, in which the nucleus pulposus remains viscous[25]. Lordotic postures increase loading of the posterior annulus, while moderately flexed postures equalise compressive stress across the disc[26].

Damage to spinal ligaments may occur if high loads are encountered in extreme postures, for example, a position of extreme trunk flexion places the posterior longitudinal ligaments and interspinous ligaments at risk if high

[18] Jäger, M., Luttmann, A., Göllner, R., & Laurig, W. (2001) The Dortmunder - Biomechanical model for quantification and assessment of the load on the lumbar spine. In: Society of Automotive Engineers (Ed.): SAE Digital Human Modeling Conference Proceedings on CD-Rom (paper 201-01-2085, 9 pp) Arlington VA.
[19] Dempsey, P.G. (1998)
[20] Granata, K.P., & Marras, W.S. (1999) Relation between spinal load factors and the high-risk probability of occupational low-back disorder. *Ergonomics*, *42*, 1187-1199.
[21] Leamon, T.B. (1994)
[22] McGill, S.M. (1997)
[23] Dolan, P. & Adams, M.A. (2001) Recent advances in lumbar spinal mechanics and their significance for modelling. *Clinical Biomechanics*, *16* (supplement). S8-S16.
[24] Adams, M.A. & Dolan, P (1995) Recent advances in lumbar spinal mechanics and their clinical significance. *Clinical Biomechanics*, *10*, 3-19.
[25] Goel, V.K., Montgomery, R.E., Grosland, N.M., Pope, M.H., & Kumar, S. (1999) Ergonomic factors in the workplace contribute to disc degeneration. In Kumar, S. (Eds.). Biomechanics in ergonomics. London: Taylor & Francis. (pp 243-265).
[26] Dolan, P. & Adams, M.A. (2001)

forces are applied. The prior history of loading of connective tissues in general influences their load tolerance[27]. For example, tasks involving prolonged static postures involving extreme trunk positions such as extreme trunk flexion cause the posterior spinal ligaments to creep, reducing the potential of these structures to provide protection during subsequent lifting activities[28]. Prolonged exposure to non-extreme static postures, for example seated postures, may also cause similar temporary mechanical changes in connective tissues which contribute to overall injury risk. Fatigue may also cause reduction in the ability of muscle to provide protection.

Estimates of exposure to lumbar compression alone provide little assistance in assessing overall back injury risk, however accurate estimates of three-dimensional forces resulting from any specific handling situation require complex biomechanical models (for examples see models provided by Lavender et al[29], McGill & Norman[30,31], Marras & Granata[32], and Marras et al[33,34]) which include consideration of dynamic factors (velocity and acceleration) as well as load and load moment throughout the movement. Even then, the accuracy of such results has been questioned due to the complexity of the structures involved[35].

Prolonged exposure to whole body vibration interacts with other risk factors, causing damage to vertebral bodies and contributing to intervertebral disc damage, probably through a reduction in disc nutrition as a consequence of damage to vertebral endplates. Standards Australia (AS 2670.1-2001) provide guidance regarding thresholds for duration of exposure to vibration of varying amplitude, but do not consider interactions with other risk factors (see McPhee et al, 2001[36] for a discussion of whole body vibration).

Neck

The head and neck is an inherently unstable complex and muscle activity is required both to balance the external moment caused by the mass of the head, and to prevent buckling of the cervical spine[37]. Neck discomfort is

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[27] Dolan, P. & Adams, M.A. (2001)

[28] McGill, S.M. (1997)

[29] Lavender, S.A., Andersson, G.B.J., Schipplein, O.D., & Fuentes, H.J. (2003). The effects of initial lifting height, load magnitude, and lifting speed on the peak dynamic L5/S1 moments. *International Journal of Industrial Ergonomics*, *31*, 51-59.

[30] McGill, S.M. & Norman, R.W. (1985) Dynamically and statically determined low back moments during lifting. *Journal of Biomechanics*, *18*, 877-885.

[31] McGill, S.M. & Norman, R.W. (1986) Partitioning of the L4/L5 dynamic moment into disc, ligamentous and muscular components during lifting. *Spine*, *11*, 666-678.

[32] Marras, W.S., & Granata, K.P. (1996) An assessment of spine loading as a function of lateral trunk velocity. *Journal of Biomechanics*, *30*, 697-703.

[33] Marras, W.S., Lavender, S.A., Leurgans, S., Rajulu, S., Allread, W.G., Fathallah, F., & Ferguson, S.A. (1993). The role of dynamic three dimensional trunk motion in occupationally-related low back disorders: the effects of workplace factors, trunk position and trunk motion characteristics on injury. *Spine*, *18*, 617-628.

[34] Marras, W.S., Lavender, S.A., Leurgans, S., Fathallah, F., Allread, W.G., Ferguson, S.A & Rajulu, S. (1995) Biomechanical risk factors for occupationally-related low back disorder. *Ergonomics*, *38*, 377-410.

[35] Dempsey, P.G. (1998)

[36] McPhee, B., Foster, G., & Long, A. (2001). Bad vibrations: A handbook on whole-body vibration exposure in mining. Sydney: Joint Coal Board Health & Safety Trust.

[37] Winters, J.M., & Peles, J.D. (1990). Neck muscle activity and 3-D head kinematics during quasi-static and dynamic tracking movements. In Winters, J.M. & Woo, S.L-Y. (Eds.). Multiple muscle systems: Biomechanics and movement organisation. New York: Springer-Verlag. (pp. 461-480).

commonly associated with prolonged exposure to static postures, typically as a consequence of visual requirements of a task. Awkward postures may also be implicated, however the complexity of the cervical spine is such that the optimal posture of the neck is not known[38]. There is some evidence that flexion of the neck beyond 30 degrees leads to more rapid onset of fatigue[39]. Prolonged exposure to static postures, and significant atlanto-occipital and cervical extension, should probably be avoided, as should significant lateral cervical flexion and rotation, although a quantitative determination of what constitutes “prolonged” and “significant” is not available. Neck injury may also be associated with forceful exertions and awkward postures involved in load handling.

Shoulder/arm

Disorders of the shoulder are similarly most frequently associated with prolonged exposure to static postures. The optimal posture of the shoulder while the trunk is upright is where the arm is vertical and the work task at about elbow height[40]. Working with unsupported elevated arms, either involving flexion or lateral flexion, requires static loading of the shoulder musculature. An epidemiological association exists between prolonged static load of the shoulders and discomfort[41]. Comprehensive threshold durations as a function of posture are not available, although evidence exists to suggest that time to fatigue increases dramatically as shoulder abduction is increased beyond 30°[42]. Individual differences in tolerance to low-level mechanical exposure is especially large[43]. Shoulder injuries also occurs during load handling, especially in awkward postures.

Wrist/Hand

Prolonged exposure to repetitive forceful exertions of the hand and wrist, especially in awkward postures, is strongly associated with tendon and nerve damage at the wrist and hand[44]. Kilbom defined work as being repetitive when the duration of the work cycle is less than 30 seconds, or when one fundamental work cycle constitutes more than 50% of the total cycle. The definition is arbitrary however, and Kilbom notes that risk may also exist for longer work cycles. Further, Kilbom notes that there is no consensus concerning the minimum duration of repetitive work, but suggests work must be performed for a minimum duration of one hour to be considered repetitive. Kilbom goes on to suggest that while symptoms might be observed for work

[38] Burgess-Limerick, R., Mon-Williams, M., & Coppard, V.L. (2000). Visual display height. *Human Factors, 42*, 140-150.
[39] Chaffin, D.B. (1973) Localized muscle fatigue: Definition and measurement. *Journal of Occupational Medicine*, *15*, 346.
[40] Winkel, J. & Westgaard, R. (2000). Occupational and individual risk factors for shoulder-neck complaints: Part II - The scientific basis (literature review) for the guide. In Mital, A., Kilbom, A., & Kumar, S. (Eds.). Ergonomics guidelines and problem solving. Amsterdam: Elsevier. (pp. 83-102).
[41] NIOSH (1997)
[42] Chaffin, D.B. (1973)
[43] Westgaard, R. (2000) Some thoughts on what we know and do not know regarding mechanical exposure – health effect relationships: what are the toolbox alternatives. In Mathiassen, S.E. & Winkel, J. (Eds.). *Ergonomics in the continuous development of production systems*. Stockholm: National Institute for Working Life. (pp. 24-28).
[44] Armstrong, T.J., Buckle, P., Fine, L.J., Hagberg, M., Jonsson, B., Kilbom, Å, Kourinka, I., Silverstein, B.A., Sjogaard, G., & Viikari-Juntura, E. (1993). A conceptual model for work-related neck and upper-limb musculoskeletal disorders. *Scandinavian Journal of Work, Environment and Health*, *19*, 73-84.

which is done for one hour, disorders are usually associated with tasks which are performed for nearly full work days. Kilbom provides a table which suggests that high risk occurs when the frequency of repetitive work exceeds 2.5 cycles/min at the shoulder, 10 cycles/min at the arm, elbow, forearm or wrist, or 200 cycles/minute for the fingers (although the last is noted to be tentative).

Clearly, however, any threshold value of repetitive work must include consideration of the level of exertion, and the postures involved, as well as the degree of repetition and duration. Kilbom acknowledges this, but suggests that no quantitative recommendations can be made concluding:

> "The risk of tendon/nerve disorders increases as the rate of movements increases or duration of the work cycle shortens. However, no "safe" levels have been identified"

and

> "no quantitative recommendations can be given concerning maximal acceptable duration of repetitive work per day, or acceptable rate of movements or contractions per time unit". [45]

More recently Kilbom[46] suggested that ordinal ratings of severity of exposure to repetitive work might be more appropriate.

Some guidance can be given regarding the range of wrist postures which should be avoided. Wrist extension of more than 30º, and ulnar deviation of more than 10º may be nominated as postures beyond which risk may be considered to be increased although no valid threshold durations are available[47,48].

Prolonged exposure to peripheral vibration associated with power tools causes neural and vascular disorders. Threshold values for peripheral vibration exposure are available, but the assessment is not trivial. Other aspects of tool design lead to additional risk. Prolonged exposure to tools which require high exertion, static or awkward postures increase risk and guidelines have been provided for appropriate tool design[49,50] however no

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[45] Kilbom, Å. (1994) Repetitive work of the upper extremity: Part 1 – Guidelines for the practitioner. *International Journal of Industrial Ergonomics*, 14, 51-57.

[46] Kilbom, Å. (2000). Internationally proposed methods for evaluation of physical work – application and modification for COPE. In Mathiassen, S.E. & Winkel, J. (Eds.). *Ergonomics in the continuous development of production systems*. Stockholm: National Institute for Working Life. (pp. 20-23).

[47] Weiss, N.D., Gordon, L., Bloom, T., So, Y., & Rempel, D.M. (1995). Position of the wrist associated with lowest carpal-tunnel pressure: Implications for splint design. *Journal of Bone and Joint Surgery (Am)*, *77*, 1695-1699.

[48] Werner, R., Armstrong, T.J., Bir, C., & Aylard, M.K. (1997). Intracarpal canal pressures: The role of finger, hand, wrist and forearm position. *Clinical Biomechanics*, *12*, 44-51.

[49] Mital, A., & Kilbom, Å. (2000) Design, selection and use of hand tools to alleviate trauma of the upper extremities: Part I – guidelines for practitioners. In Mital, A., Kilbom, A., & Kumar, S. (Eds.). Ergonomics guidelines and problem solving. Amsterdam: Elsevier. (pp. 213-216).

[50] Mital, A., & Kilbom, Å. (2000b) Design, selection and use of hand tools to alleviate trauma of the upper extremities: Part 2 – The scientific basis (knowledge base) for the guide. In Mital, A., Kilbom, A., & Kumar, S. (Eds.). Ergonomics guidelines and problem solving. Amsterdam: Elsevier. (pp. 217-230).

thresholds for duration of use are available. Exposure to cold also interacts with tool use[51], as does the wearing of gloves.

Lower limbs
Lower limb injuries due to manual tasks are relatively rare, however prolonged exposure to static postures, or forceful exertions associated with foot pedals, and awkward postures such as extreme knee flexion may lead to damage to muscle or other connective tissue. Long duration eccentric contractions such as associated with stair descent will lead to delayed onset muscle soreness, and knee ligaments are susceptible to impact loading due to landing as sometimes occurs during vehicle egress.

Conclusion

Sufficient epidemiological and biomechanical evidence exists to support a conclusion that prolonged and/or repetitive exposure to forceful exertions, awkward and static postures, and vibration constitute risks of musculoskeletal injury. However: anatomical complexity makes accurate estimates of tissue loading difficult to obtain; there are large individual differences in load tolerance; interactions occur between physical risk factors; and interactions occur between physical risk factors and environmental and psychophysical risk factors. The result is that it is not possible to define valid threshold limit values for risk factors associated with manual tasks.

[51] Holmér, I. (2000).Cold stress: Part I – guidelines for practitioners. In Mital, A., Kilbom, A., & Kumar, S. (Eds.). Ergonomics guidelines and problem solving. Amsterdam: Elsevier. (pp. 329-336).

Threshold limit values in regulations and advisory documents

Appendix B contains a summary of the use of quantitative thresholds in regulatory and advisory documents in selected jurisdictions both nationally and internationally. A consistent feature of the documents reviewed is the risk management approach which aims to motivate and facilitate manual task risk identification, assessment, and control. Most jurisdictions provide checklists to assist in risk identification which require dichotomous yes/no responses to qualitative, and sometimes quantitative, questions. Longer, and slightly more detailed checklists are typically provided to assist in risk assessment. The role played by threshold limit values in regulation and advice varies considerably, particularly internationally.

Australia

The 1990 Australian National Standard and Code of Practice[52] departed from the previous practice of exclusive reliance on weight limits, but retained remnants of the previous approach in providing threshold values of 4.5 kg for seated work and 16 kg for other work (and confusingly, a further "maximum" of 55 kg) in both the risk identification and risk assessment checklists, as well as specifying a threshold of 16 kg for workers under the age of 18 years. Quantitative dimensions for loads are provided, and the 1994 Code of Practice for the Prevention of Occupational Overuse Syndrome[53] includes quantitative thresholds for durations, and task characteristics, in both risk identification and risk assessment checklists.

Western Australia

The Western Australian Manual Handing Code of Practice[54] risk assessment checklist departs from the typical yes/no format by suggesting a "not applicable" or "low/medium/high" severity rating. Little assistance in making this determination is provided however. The WA document also duplicates the remnant weight thresholds contained in the national code.

Queensland

The Queensland Manual Tasks Advisory Standard[55] adopts Kilbom's[56] definition of repetitive work, and provides duration thresholds of four hours over an eight hour shift for repetitive work, and a two hour duration threshold for qualitatively defined work postures. The advisory standard does not contain any weight thresholds, but does refer to the NIOSH equation and psychophysical data suggesting that weight limits might be derived from these for particular industries.

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[52] NOHSC (1990) *National standard for manual handling and national code of practice for manual handling*. Canberra: AGPS.

[53] NOHSC (1994) *National code of practice for the prevention of occupational overuse syndrome*. [NOHSC:2013] Canberra:AGPS

[54] Worksafe WA (2000) *Code of practice: Manual handling*. Worksafe Western Australia.

[55] DWHS (1999)

[56] Kilbom, Å. (1994)

Victoria

The risk assessment tool provided within the Victorian Manual Handling Code of Practice[57] contains quantitative definitions for awkward postures, repetition and duration, but not force or weight. Controls are required to be put in place for tasks which exceed these quantitative (or other qualitative thresholds) if they are performed either more frequently than twice per minute or for more than 30 seconds, *and* for more than two hours per shift or continuously for more than 30 minutes. The Victorian code also suggests that quantitative tools including the NIOSH lifting equation, psychophysical tables, OWAS and REBA may be useful in some circumstances.

United Kingdom

The United Kingdom manual handling regulations of 1992 do not specify threshold limits, the guidance materials on the regulations noting that:

> “The ergonomic approach shows clearly that such requirements are based on too simple a view of the problem and are likely to lead to incorrect conclusions” [58].

However the guidance material provides quantitative minimum thresholds, below which risk of injury is believed to be low are provided. A threshold for lifting of 25 kg in ideal situations is provided (for males), and this value is reduced as a function of load distance, lifting height, and lift frequency, with lower values provided for females. Minimum threshold values are also provided for pushing or pulling, and lifting while seated. Threshold durations of either two consecutive hours, or two hours total per shift, are also provided for various qualitatively defined risk factors in the recent HSE document on preventing upper limb disorders[59]. A threshold of 2.8 $m/s^2A(8)$ is nominated for exposure to peripheral vibration.

Sweden

The Swedish regulations and guidance materials are similar to the UK in not providing threshold limits, noting:

> Whether or not a lifting and carrying job is harmful will depend on many simultaneous factors: what is lifted, how the lifting is done, in what environment and who does the lifting or carrying. This makes it very difficult to define an absolute limit value for just one of these factors, such as the maximum permissible weight of a load[60]

but at the same time providing thresholds for a Red/Yellow/Green “traffic light” model. A maximum weight of 25 kg is reduced as a function of load distance, but without consideration of any other factors. Thresholds are similarly provided for push/pull forces.

[57] Victorian Workcover Authority (2000) *Code of practice for manual handling*. Melbourne: VWA.
[58] HSE (1998) *Manual handling: Guidance on regulations.* 2nd Edition. HSE Books: UK. (p. 3).
[59] HSE (2002). *Upper limb disorders in the workplace*. HSE Books: UK.
[60] SNBOSH(1998) *Ergonomics for the prevention of musculoskeletal disorders* [AFS 1998:1]. Stockholm: Swedish National Board of Occupational Safety and Health. (p. 25).

United States of America

The ill-fated OSHA ergonomics rule did not provide weight limits, or threshold limit values for other risk factors, with the exception Kilbom's[61] definition for high repetition risk (2.5 reps/minute for shoulder, 10 reps/min for upper arm, elbow, forearm or wist, and 200 reps/min for fingers). Qualitative assessments of risk exposure were sufficient to satisfy the requirements of the OSHA rule, however quantitative methods such as the NIOSH lifting equation, Snook tables, and RULA were cited.

Washington State

The Washington State ergonomics rule promulgated in 2001 provides the most detailed threshold limits of the jurisdictions considered[62]. The Washington State rule requires employers who have one or more "caution zone" jobs (as defined semi-quantitatively in WAC 296-62-05105) to analyse these jobs and reduce the hazards below a threshold level defined by either "widely used methods" (eg., Job Strain Index, NIOSH lifting equation, REBA, RULA), or limits provided in an appendix of the rule. The appendix provides duration thresholds for quantitatively defined awkward postures, as well as combinations of force, repetition and posture for upper limbs. Threshold values for load weight are also provided as a function of lift height, distance from the trunk, twisting, lift frequency and duration. The maximum weight for a load lifted less frequently than once every five minutes, from a height between knee and waist and held close to the body, and lifted without rotation is 41 kg. Threshold values are also provided for hand-arm vibration.

Conclusion

Whilst the two step risk identification and assessment model is common to all the jurisdictions reviewed, it is clear that there is no commonly agreed set of threshold values for individual risk factors or combined risk factors which might be adopted. This not surprising given the previously noted difficulties in deriving valid threshold values based on current evidence.

To recap, whilst knowledge about the relationships between risk factors exists, there are a number of difficulties with the provision of quantitative threshold values for manual tasks. Anatomical complexity and individual variability in tissue tolerances, combined with the interactions between biomechanical, environmental, and psychosocial risk factors makes the assessment of manual task risk and the determination of valid threshold values exceptionally difficult.

Consequently, it is recommended that:

1. *Quantitative threshold limit values for weight, force, or other risk factors should not be provided within manual tasks regulation or advisory materials.*

[61] Kilbom, Å. (1994)

[62] Washington State (2001) Ergonomics rule. http://www.lni.wa.gov/wisha/regs/ergo2000/ergowac.htm

This is consistent with the view expressed in an issues paper prepared for the 1998 review of the Victorian regulations and code of practice in which it was noted that:

> "Workcover believes that it would be inappropriate to specify exposure limits, that is, threshold limit values (TLV) in a hazard identification or the risk assessment duty applying to manual handling tasks."[63].

Although manual task risk assessment does not necessarily require the use of formal tools, the complexity of some manual tasks makes the availability of a tool desirable. While dichotomous yes/no checklists may be useful for hazard identification, the complexity of the problem of assessing risk due to manual tasks is such that greater assistance is required by employers than that provided currently by Australian jurisdictions. This is implicitly recognised in current Queensland and Victorian advisory documents by the citation of tools such as the NIOSH equation, psychophysical tables, RULA and REBA. In the following section, criteria for an appropriate risk assessment tool are derived, and an assessment is provided of currently available tools.

[63] VWA (1998) *Issues paper: Review of manual handling regulations 1988 and associated codes of practice.* Melbourne: Victorian Workcover Authority.(p. 44).

Criteria for a risk assessment tool

Many of the quantitative tools which have been provided are only strictly applicable in very limited circumstances. A temptation exists to apply the tools in situations to which they are unsuited, with the potential for misleading results. There is also the pragmatic problem of providing a range of tools to cover the broad definition of manual tasks. An appropriate risk assessment tool must be sufficiently general to be used with the complete range of manual tasks[64].

As outlined above, multiple factors are simultaneously implicated in injury causation. While exposure to a single risk factor alone may cause injury, injuries are far more likely when exposure to multiple risk factors occurs and consequently it is essential that a risk assessment tool allow assessment of multiple biomechanical risk factors simultaneously.

Some tools attempt to provide a global assessment of manual task risk across the whole body. This approach is flawed given that injury occurs to a specific anatomical structure. An appropriate tool must incorporate independent assessment of the risk to different body regions

The nature of the cumulative causal mechanisms involved, and the individual differences in tissue tolerances, is such that dichotomous threshold values are inevitably inappropriate. Seldom, if ever, can it be said that on one side of a threshold lies safety, while on the other lies injury. Risk is always a function of exposure, and while the function may not be linear, it will never be a step function. Risk assessment tools should acknowledge this, providing an indication of the severity of risk to facilitate effective prioritisation of controls, rather than simply presence or absence of risk. On the other hand, there is a danger in the use of quantitative tools which provide greater precision than is warranted[65]. For a tool to be useful to industry, it is also necessary to provide guidance regarding thresholds beyond which action is desirable.

A common response to these difficulties of providing quantitative threshold values has been to provide checklists comprised of “yes/no” questions, most of which involve qualitative assessment of the presence or absence of a risk factor. Such checklists are of limited utility, in particular because they provide little assistance in determining the relative threats posed by different risk factors, or the priority attached to different tasks in any way beyond the “number of yes” responses. Such checklists may be useful as part of a risk identification process, however an appropriate tool for manual task risk assessment should provide an indication of the relative contribution of different risk factors to the overall risk to facilitate effective targeting of controls.

[64] Hansson, G-Å (2000) Measuring physical/mechanical work load for various task activities in production systems – methods applied in COPE. In Mathiassen, S.E. & Winkel, J. (Eds.). *Ergonomics in the continuous development of production systems.* Stockholm: National Institute for Working Life. (pp. 10-12).
[65] Kilbom, Å. (2000)

Some tools suffer from being overly complex or requiring specialist equipment which makes them unsuitable to reference in regulation or standard. An appropriate risk assessment tool should not require specialist equipment and should be useable by workplace staff with limited training.

It is recommended that:

2. *advisory materials related to manual tasks injury prevention should include an optional risk assessment tool which:*

a) is applicable to the complete range of manual tasks
b) provides an integrated assessment of biomechanical risk factors
c) provides an independent assessment of injury risk to different body regions
d) provides an overall risk assessment which allows prioritisation of tasks and incorporates suggested action thresholds, but does not imply misleading level of precision
e) facilitates effective targeting of controls by providing an indication of the relative severity of different risk factors within a task
f) is suitable for use by workplace staff with minimal training and equipment

Candidate Risk Assessment Tools

The following section provides an assessment of selected risk assessment tools against the above criteria.

Revised NIOSH Lifting Equation

The revised NIOSH equation[66] provides a method for determining the recommended weight limit for a particular task taking into account: a) the horizontal distance of the load; b) the initial height of the load; c) the vertical distance of the lift; d) frequency of the lift; e) duration of the task; f) initial degree of trunk rotation; and g) quality of handles provided. The equation assumes smooth, two handed movements, and does not apply to tasks: involving durations greater than 8 hours; performed while seated or kneeling; in restricted work spaces; involving unstable objects; carrying, pushing, or pulling; involving tools such as wheel barrows or shovels; on slippery floors; or in unfavourable environmental conditions[67].

The recommended weight limit derived is based on a threshold for lumbar compression of 3.4 kN which yields a recommended weight limit in optimal circumstances of 23 kg. This limit is not protective of older workers. The equation has also been criticised for its restricted applicability and usability,[68] and concerns have been expressed regarding the applicability of the asymmetry multiplier added to the revised equation[69]. Most recently, it has been determined that the equation underestimates forces associated with lifting low loads[70]. Whilst the NIOSH equation has utility as a pedagogical tool, it fails to fully satisfy criteria a-d listed above for a satisfactory risk assessment tool.

As noted earlier, it is clear that a focus on lumbar compression alone is inappropriate. Granata & Marras, for example, demonstrated that static estimates of compression accounted for only 13% of the probability of high risk group membership.[71] Consideration of dynamic loading, and loading other than compression, is clearly necessary for an accurate determination of risk. Whilst three-dimensional dynamic models exist, they come at high cost in terms of measurement complexity (see Jager et al[72] and Neumann et al[73] for examples) and such techniques are unsuitable for general field use.

[66] Waters, T.R., Putz-Anderson, V., Garg, A., & Fine, L.J. (1993)

[67] Waters, T.R., & Putz-Anderson, V. (1999). Revised NIOSH lifting equation. In Karwowski, W., & Marras, W.S. (Eds.). The occupational ergonomics handbook. Boca Raton: CRC. (pp. 1037-1061).

[68] Dempsey, P.G. (2002)

[69] Dempsey, P.G., & Fathallah, F.A. (1999)

[70] Lavender, S.A., Andersson, G.B.J., Schipplein, O.D., & Fuentes, H.J. (2003)

[71] Granata, K.P., & Marras, W.S. (1999) Relation between spinal load factors and the high-risk probability of occupational low-back disorder. *Ergonomics*, *42*, 1187-1199.

[72] Jäger, M., Jordan, C., Luttmann, A., Laurig, W., & DOLLY Group (2000) Evaluation and assessment of lumbar load during total shifts for occupational manual materials handling jobs within the Dortmund Lumbar Load Study - DOLLY. *International Journal of Industrial Ergonomics*, *25*, 553-571.

[73] Neumann, W.P., Wells, R.P., Norman, R.W., Frank, J., Shannon, H., Kerr, M.S. & the OUBPS Working Group (2001). A posture and load sampling approach to determining low-back pain risk in occupational setting. *International Journal of Industrial Ergonomics*, *27*, 65-77.

Psychophysical approaches
The subjectively determined maximum acceptable weights provided by Snook & Ciriello[74] are a relatively simple way of determining quantitative threshold values for manual handling, and analogous values exist for forces applied in various directions and situations (for example see Snook et al[75]). However, evidence is not available to demonstrate that psychophysically determined thresholds provide protection from injury[76] and Marras et al[77] concluded that psychophysical criteria did not correctly identify known high risk tasks. Concern has been expressed regarding generalising psychophysical limits determined during short exposures to work situations of longer durations, especially for high frequency tasks[78]. Psychophysical approaches do not satisfy four of the above criteria (a, c, d, & e).

OWAS
The Ovako Working Posture Analysis System (OWAS)[79] involves coding of back (4 levels), arm (3 levels) and lower limb posture (7 levels), as well as an assessment of force (three levels) at frequent intervals (usually 30 or 60 seconds). The task is assigned to one of four action categories based on either combinations of postures, or the proportion of time spent in different postures. While the technique does allow differentiation of risk between back, arms and legs based on posture, as well as providing a whole body assessment which encompasses posture and force, the postural coding is relatively crude, and time consuming if performed for long periods, and other risk factors (repetition, duration and vibration) are not considered. OWAS fails to satisfy criteria b and e above.

RULA & REBA
The Rapid Upper Limb Assessment tool (RULA)[80] was conceptually based on OWAS, and provides a relatively simple means of assessing the risk of upper limb disorders associated with a task. The tool incorporates scores for postures across different body regions, and ratings of exertion using a four point scale, which are combined to produce a single score between 1 and 7. While the tool is relatively simple, and allows a rapid assessment of upper limb risk which integrates posture & exertion, it does not incorporate consideration of other risk factors (eg., repetition, duration & vibration). Based on RULA, McAtamney & Hignett[81] provided a Rapid Entire Body Assessment

[74] Snook, S.H., & Ciriello, V.M. (1991) The design of manual handling tasks: Revised tables of maximum acceptable weights and forces. *Ergonomics*, *34*, 1197-1213.
[75] Snook, S.H., Vaillancourt, D.R., Ciriello, V.M., & Webster, B.S. (1995). Psychophysical studies of repetitive wrist flexion and extension. *Ergonomics*, *38*, 1488-1507.
[76] Dempsey, P.G. (1999). Prevention of musculoskeletal disorders: Psychophysical basis. In Karwowski, W., & Marras, W.S. (Eds.). The occupational ergonomics handbook. Boca Raton: CRC. (pp. 1101-1126).
[77] Marras, W.S., Fine, L.J., Ferguson, S.A., & Waters, T. (1999) The effectiveness of commonly used lifting assessment methods to identify industrial jobs associated with elevated risk of low-back disorders. *Ergonomics*, *42*, 229-245.
[78] Dempsey, P.G. (1998)
[79] Karhu, O., Kansi, P., & Kourinka, I. (1977) Correcting working postures in industry. A practical method for analysis. *Applied Ergonomics, 8*, 199-201.
[80] McAtamney, L., & Corlett, E.N. (1993). RULA: A survey method for the investigation of work-related upper limb disorders. *Applied Ergonomics*, *24*, 91-99.
[81] McAtamney, L., & Hignett, S. (1995)

tool (REBA) which similarly combines posture and force assessments to provide a single score. RULA and REBA fail to satisfy criteria b and e above.

OCRA

Occhipinti[82] suggested a method for assessing exposure to repetitive movements of the upper limb in a way conceptually similar to the NIOSH lifting equation. A hypothetical action frequency of 30 movements per minute is reduced by multipliers corresponding to exertion, posture, recovery time, and “additional elements”. The method assesses upper limb injury risk only, and has the potential (similar to the NIOSH equation) of providing a misleading degree of precision. OCRA fails to satisfy a, c, and d.

Strain Index

Moore and Garg[83] proposed a semi-quantitative method for assessing tasks with respect to the risk of distal upper extremity disorders. The method involves rating 6 task variables (exertion intensity, speed, frequency & duration, wrist posture and task duration per day) on a five point ordinal scale and converting these ratings into a single Strain Index. The method has face validity, and satisfies a number of requirements for a risk assessment tool. It does have the limitation of only providing an assessment of risk of injury to one body region, and neglects exposure to vibration as a contributing risk factor. The Strain Index fails to satisfy criteria a and c.

Quick Exposure Check

Li & Buckle[84] have proposed a checklist of 15 items to assess risk exposure to Back, Shoulder/arm, Wrist/hand & Neck encompassing ratings of posture, movement frequency, weight handled, duration, exertion, vibration, and stress. The checklist satisfies a number of requirements for an appropriate risk assessment tool in that multiple risk factors are combined and a scoring system is provided to combine risk factor ratings for each body region. However, while ordinal scales are provide rather than yes/no answers, the level or precision is generally low with only three point scales used (with the exception of four point scales for “force level exerted” and “how stressful do you find this work”). There is also no indication provided of appropriate threshold values for action. The Quick Exposure Check fails to satisfy criteria d and e above.

ManTRA

A Manual Tasks Risk Assessment tool (ManTRA)[85] was developed as part of a research collaboration between The University of Queensland, Curtin University of Technology, and the Queensland Division of Workplace Health and Safety (funded by Workcover Queensland [QComp] and the National

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[82] Occhipinti, E. (1998). OCRA: a concise index for the assessment of exposure to repetitive movements of the upper limbs. *Ergonomics*, *41*, 1290-1311.

[83] Moore, J.S., & Garg, A. (1995) The strain index: A proposed method to analyze jobs for risk of distal upper extremity disorders. *American Industrial Hygiene Association Journal*, 56, 443-458.

[84] Li, G., & Buckle, P. (1999) *Evaluating change in exposure to risk for musculoskeletal disorders – a practical tool*. HSE Books CRR 251/1999.

[85] Burgess-Limerick, R., Egeskov, R., Straker, L., & Pollock, C. (2000). Manual tasks blitz audit tool. Unpublished document. Division of workplace health and Safety, Department of Industrial relations, Queensland.

Health and Medical Research Council). The tool was designed for use by inspectors during workplace audits to provide an assessment of the level of risk of injury associated with specific workplace tasks. The tool (presented with explanatory notes in Appendix C) is conceptually related to the Strain Index and Quick Exposure Check. An assessment is required (on a five point ordinal scale) for each of five body regions of the total exposure per shift to each of the following risk factors: Repetition (incorporating independent ratings of duration and cycle time); Exertion (incorporating independent ratings of force and speed); Awkward postures; and Vibration. Suggested thresholds for action are provided for exertion; exertion and awkwardness combined; and total exposure.

ManTRA has the advantage of allowing the interactions between relevant biomechanical risk factors to be assessed simultaneously for independent body regions. The tool provides an appropriate degree of precision, allowing greater guidance than a dichotomous checklist without implying misleading precision. Experienced inspectors were able to use the tool effectively following a half day training session, and the tool has been used to assess manual task risk in more than 400 workplace audits with positive feedback. ManTRA satisfies the above criteria for a risk assessment tool, with the exception of the final criterion relating to usability by workplace staff with minimal training. The current version of ManTRA was designed for use by workplace health and safety inspectors, and a simplified version may be necessary for general use.

Conclusion

While satisfactory manual tasks risk assessments may be completed without a formal tool in some situations, where the task is complex, the use of a tool which satisfies the above criteria may be advantageous. The Manual Tasks Risk Assessment tool (ManTRA) best meets the above criteria, with the exception of the extent of training required in its use.

It is recommended that*:*

5. a simplified version of ManTRA should be provided within advisory documents to assist manual task risk assessment; and

Ideally, manual task risk assessment and control should be performed by workplace teams including employees who perform the tasks being assessed, as well as staff responsible for managing manual tasks risk at the workplace. Consequently:

6. appropriate training materials should be developed to support manual task risk management by employees and management.

Appendix A

Manual Tasks Injury Mechanisms

Bone

Although fracture of bone can occur as a consequence of a single application of high load, an accumulation of microdamage in excess of the tissues capacity to repair leading to stress fracture is more common in occupational situations. Damage to bone associated with manual tasks most commonly occurs in the spinal vertebrae as a consequence of prolonged exposure to repetitive forceful exertions, awkward postures, and whole body vibration[86].

Muscle

Acute injury to muscle occurs as a consequence of loading which exceeds the tolerance of the tissue, and this is particularly likely during eccentric contractions[87]. Cumulative injury also occurs as a consequence of prolonged exposure to isometric muscle activation such as occur when muscle tension develops in the absence of movement. The mechanism by which this occurs is not completely understood, but probably involves disruption to microcirculation in the preferentially recruited type one muscle fibres[88]. Injury to muscle may also occur as a consequence of prolonged exposure to repetitive movements[89]. Muscle fibre strength is highly dependent on fibre length which varies with joint posture, and extremes of joint posture may place muscle fibres at increased risk. Risk factors associated with injury to muscle are thus prolonged or repetitive exposure to high exertion, static or awkward postures; as well as single application of very high force.

Other connective tissues

Tendons and ligaments are susceptible to acute injury through exposure to high load, and have a much reduced capacity for repair in comparison to muscle due to their relatively poor blood supply[90,91]. Acute injury to ligaments is likely when large forces are exerted when a joint is at end range. Cartilage is even slower to repair, and is susceptible to damage due to prolonged exposure to repetitive impact loads[92]. Cumulative damage to tendons appears to occur most frequently in situations in which tendons are loaded simultaneously in both tension (due to muscular contraction) and transverse reaction forces due to passing over adjacent structures. These reaction forces are generally higher as joint postures approach end range. Risk factors associated with tendon, ligament and cartilage injury are forceful exertions, and particularly, prolonged exposure to repetitive forceful exertions in awkward postures.

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86 Adams, M.A. & Dolan, P (1995)
87 Edwards, R.H.T. (1988). Hypothesis of peripheral and cental mechanisms underlying occupational muscle pain and injury. *European Journal of Applied Physiology*, *57*, 275-281.
88 Sjogaard, G., & Jenson, B.R. (1999) Low level static exertions. In Karwowski, W., & Marras, W.S. (Eds.). The occupational ergonomics handbook. Boca Raton: CRC. (pp. 247-259).
89 Kilbom, Å. (1994)
90 Timmermann, S.A., Timmermann, S.P., Boorman, R., & Frank, C.B. (1999). Ligament sprains. In Kumar, S. (Ed.). *Biomechanics in Ergonomics.* London: Taylor & Francis. (pp. 45-57).
91 Woo L.-Y., Apreleva, M. & Höher, J. (1999) Tissue mechanics of ligaments and tendons. In Kumar, S. (Ed.). *Biomechanics in Ergonomics.* London: Taylor & Francis. (pp. 27-43).
92 Radin, E.L., & Paul, I.L. (1971). Response of joints to impact loading I: In vitro wear. *Arthritis and Rheumatology*, *14*, 356-362.

Nerves
Pressure applied to nerves inhibits function and causes dose dependent microscopic changes. Acute effects reverse rapidly. Prolonged exposure causes irreversible effects, although the critical thresholds are unknown[93,94]. Nerve compression typically occurs where nerves pass through other structures, such as the carpal tunnel. In such situations, pressure is increased as joint posture approaches end range, and with loading[95]. The effects of pressure appear to be exacerbated by exposure to cold, and risk factors associated with nerve damage include prolonged or repetitive exposure to awkward postures, especially in cold environments. A strong association also exists between prolonged exposure to peripheral vibration and nerve damage. The mechanism by which the damage occurs is not fully understood, however structural changes have been observed in the nerve fibres of patients exposed to peripheral vibration.

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. A more common vascular injury is the permanent changes to peripheral circulatory function which occur as a consequence of prolonged exposure to peripheral vibration.

[93] Rempel, D., Dahlin, L., & Lundborg, G. (1999). Biological response of peripheral nerves to loading: Pathophysiology of nerve compression syndromes and vibration induced neuropathy. In NRC (1999) *Work-related musculoskeletal disorders.* Washington: National Academy Press. (pp. 98-115).
[94] Wells, R., & Keir, P. (1999) Work and activity-related musculoskeletal disorders of the upper extremity. In Kumar, S. (Ed.). *Biomechanics in Ergonomics.* London: Taylor & Francis. (pp. 165-177).
[95] Rempel, D., Manojlovic, R., Levinsohn, D.G., Bloom, T., & Gordon, L. (1994) The effect of wearing a flexible wrist splint on carpal tunnel pressure during repetitive hand activity. *Journal of Hand Surgery (Am)*, *19*, 106-110.

Appendix B

Threshold Values in Selected National and International Jurisdictions

Current Australian National Standard and Code of Practice

The current National Standard for Manual Handling and Code of Practice for Manual Handling were based on Victorian regulations and the associated code of practice promulgated in 1988. A significant feature of these documents was the departure from the exclusive use of weight limits as a means of controlling exposure to manual handling risk factors. Indeed, the preface to the current national documents states:

> "The principal feature of this national code of practice is the provision of a multi-factorial approach to risk identification, assessment and control to be applied to manual handling tasks. This was considered to be a more appropriate method than the exclusive use of weight limits alone"[96].

The current national standard (section 4.1) requires an employer to ensure that "manual handling, which is likely to be a risk to health and safety, is examined and assessed"[97], and this assessment shall take into account a list of factors (section 4.3) including actions and movements, posture, duration and frequency of handling, location of loads, distances moved, and weights and forces as well as other factors. A risk identification checklist consisting of 18 "Yes/No"questions is provided to assist employers determine whether a task requires further assessment. Any "yes" answer indicates the need for further risk assessment. The risk identification checklist includes qualitative questions relating to working postures (eg., Is there frequent or prolonged reaching above the shoulder?; Is there frequent or prolonged twisting of the back?) and some aspects of load handling (eg., Is manual handling performed frequently or for long time periods by the employee(s)?; Are loads moved or carried over long distances?; For pushing, pulling or other application of forces: are large push/pulling forces involved). The only quantitative threshold values provided in the risk identification checklist are three questions regarding object weight, viz:

Q 8. Is the weight of the object:

- more than 4.5 kg and handled from a seated position?
- more than 16 kg and handled in a working posture other than seated?
- more than 55 kg?

A note is provided:

> "*Weight is not used to prescribe absolute limits, but is one of the important features to be considered when assessing and controlling risk.*"[98].

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[96] NOHSC (1990) p. vii
[97] NOHSC (1990) p. 8
[98] NOHSC (1990) p. 28, emphasis in original

Part c “more than 55 kg” has questionable relevance given that a “yes” response would already have been made to part b, thus triggering further assessment.

Section 4 of the current National Code of Practice provides guidance on the assessment of the 14 factors stipulated by the national standard. The guidance provided in this section primarily takes the form of more detailed “Yes/No” questions. Qualitative thresholds are provided (eg., During manual handling, is there frequent or prolonged above shoulder reach?; When sliding, pulling or pushing an object, is the object difficult to move?) with the exception of object weight and dimensions. In relation to object weight the code provides the following guidance:

> 6.23 For lifting, lowering or carrying loads:
>
> a) in seated work, *it is advisable* not to lift loads in excess of 4.5 kg;
>
> b) some evidence shows that the risk of back injury increases significantly with objects above the range of 16-20 kg, therefore, from the standing position, *it is advisable* to keep the load below or within this range;
>
> c) as weight increases from 16 kg up to 55 kg, the percentage of healthy adults who can safely lift, lower or carry the weight decreases. Therefore more care is required for weights above 16 kg and up to 55 kg in the assessment process. Mechanical assistance and/or team lifting arrangements *should be provided* to reduce the risk of injury associated with these heavier weights; and
>
> d) generally, no person should be required to lift, lower or carry loads above 55 kg, unless mechanical assistance or team lifting arrangements are provided to lower the risk of injury.
>
> and
>
> **4.41** Young workers under the age of 18 years should not be required to lift, lower or carry objects weighing more than 16 kg without mechanical or other assistance which may include team lifting and/or particular training for the task.

Quantitative questions are also provided for object width (is the object wider than 50 cm), length (is the object more than 30 cm long) and combined dimensions (Are any two of the object’s dimension more than 75 cm?). The code suggests that a “yes” answer to any of these questions “indicates an increased risk”.

The current National Code of Practice for the Prevention of Occupational Overuse Syndrome[99] (NOHSC, 1994) similarly provides a 29 question risk identification checklist (which encompasses the checklist from the National Code of Practice for Manual Handling). Many questions are predominantly qualitative (eg., Does the task require maintaining a fixed or awkward

[99] NOHSC (1994)

position, particularly of the neck and/or arms?; Are the tools and equipment awkward or uncomfortable to use?). However the risk identification checklist[100] includes the following questions which imply quantitative thresholds:

> 3. Is there a vertical distance of travel of more than 25 cm?
>
> 4. Is frequent or prolonged reaching forward (more than 30 cm away from the body) involved?
>
> 6. Does any action require maintaining a force, for ample, holding a grip or position for more than 10 seconds?
>
> 8. Is the task done for more than one hour at a time?
>
> 9. Is the task done more than once every five minutes?
>
> 10. Are similar actions repeated for more than one hour in a work day or shift?

Appendix 3 of the National Code of Practice for the Prevention of Occupational Overuse Syndrome provides a 28 question Risk Assessment Form which again provides predominantly qualitative descriptors (eg., Does the layout of the workplace result in excessive twisting or bending of the neck, shoulders or upper body?; Is the employee required to bend frequently at low working heights to handle objects?). Quantitative thresholds are implied by the following questions:

> 10. Does the task require the employee to work with arms outstretched from the body for at least one minute without rest?
>
> 11. Does the task require an employee to work continuously or repetitively above shoulder level for at least 30 seconds?
>
> 13. Does the task require an employee to maintain an awkward position for at least 30 seconds?
>
> 20. Are there any repetitive tasks which require an employee to maintain an unsupported fixed position and take longer than 30 seconds?

Western Australian Code of Practice: Manual Handling

The current Western Australian code of practice provides less detailed guidance in the area of hazard identification than the National Code, but provides a risk assessment form[101] which requires rating risk factors such as “holding loads away from the trunk” as “not applicable”, “low”, medium” or “high” rather than just noting presence or absence of the risk factor. Appendix H of the WA code provides some guidance for rating the severity of the risk factors which is qualitative in nature (eg., the risk of injury increases with the degree of sideways bending to handle a load) with the exception of load

[100] NOHSC (1994) Appendix 2
[101] Worksafe WA (2000) Appendix E

dimension and weight. In the area of load dimension the WA code suggests in section 1.8 of Appendix H "When any dimension is more than 75 cm a greater risk is incurred. This risk is higher again if two dimensions are more than 75 cm"[102], and in section 2.2 of that Appendix "Where a load's width (measured across the body) is more than 50 cm, there is an increased risk".

In section 2.1 of Appendix H the WA code[103] suggests that:

> *The risk of injury increases as the weight of a load increases.*
>
> Evaluating the risk of weight of the object needs to take into account:
>
> - How long the load is handled; and
> - How often the load is handled.
>
> As a guide, the risk of back injury increases when loads over 4.5 kg are handled from a seated position or when loads over 16 kg are handled from positions other than seated. As weight increases, the percentage of healthy adults who can safety (sic) lift, lower or carry decreases.
>
> Generally, no single person should be required to lift, lower or carry loads over 55 kg. **THIS LIMIT WOULD ONLY APPLY, HOWEVER, WHEN THE LOAD IS WITHIN THE PERSON'S CAPABILITIES AND NO OTHER RISK FACTORS ARE PRESENT** (eg. No bending or twisting is required to pick up the load; the load is compact and easy to grasp; it is held close to the trunk and not carried frequently or for long distances).
>
> On occasions, objects over 55 kg may be moved but not lifted, eg. rolling a 200 litre drum.

Queensland Manual Tasks Advisory Standard

The Queensland manual tasks advisory standard identifies direct risk factors (forceful exertions, working postures, repetition and duration, vibration), contributing risk factors (work area design, tool use, nature of loads, load handling) and modifying risk factors (work organisation, individual factors), provides detailed checklists for each risk factor to assist in the risk identification process. The checklists in the main are qualitative Yes/No, although a quantitative definition of repetitive work is provided in section 10.3[104] viz:

> Work is considered **repetitive** when –
>
> - The duration of a work cycle is less than 30 seconds; or
> - A fundamental activity on the work cycle is repeated for more than 50% of the work cycle time …

[102] Worksafe WA (2000) p. 41
[103] Worksafe WA (2000) p. 41-42, emphasis in original
[104] DWHS (1999) p. 39, emphasis in original

> Work must be performed continuously for a minimum of 60 minutes in order to be considered repetitive.

other checklist questions implying a quantitative threshold are:

Is high repetition work over 4 hours in total distributed through an eight-hour shift?

Are any of the following work postures sustained for more than a total of 2 hours
a) working with the back bent forward?
b) overhead work?
c) work with arms out from the body with elbows at or above mid-trunk height?
d) bent wrists
e) kneeling or squatting

Are tools of more than 1.5 kg used without aids to assist in supporting them?

Do tools require use of a wide grip span which is excessive (more than 10 cm) or cause discomfort?

Does the design of a trigger allow it to be locked on if activated for more than 30 seconds?

Guidance material also suggests that workplace design should "eliminate routine horizontal reaches over 30 cm from sitting and 50 cm from a standing position"[105]. The effective weight of tools (the weight supported by workers) should be not more than 1.75 kg for precision tools, and not more than 2.3 kg for power tools, and the grip span less than 9 cm, according to section 10.6. Appropriate load dimensions are given as less than 50 cm wide, 30 cm long, and any two dimensions less than 75 cm. Dimensions for handles are also provided.

The Queensland Manual Tasks Advisory Standard does not provide any weight limits, but does provide an Appendix which describes the dependence of muscular effort on factors other than load weight. Appendix 4 of the advisory standard states:

> "Arbitrary weight limits for loads to be handled manually cannot be set because of the many factors involved"[106].

The Appendix goes on to cite the 1981 NIOSH Work practices guide for manual lifting (no longer available) and tables of recommended weight limits, suggesting that:

> "Recommendations for a weight limit in a particular industry could be made by consulting either tool, deciding on a general combination of handling circumstances and deriving a value"[107].

[105] DWHS (1999) p.36.
[106] DWHS (1999) p.72
[107] DWHS (1999) p.72

Victorian Code of Practice for Manual Handling

The Victorian code[108] requires an employer to determine whether a task involves hazardous manual handling, and if so, to perform a risk assessment. The hazard identification involves a qualitative determination of whether the task involves any of:

- repetitive or sustained application of force
- repetitive of sustained awkward posture
- repetitive or sustained movement
- application of high force
- exposure to sustained vibration
- manual handling of live people or animals
- manual handling of loads that are unstable, unbalanced or difficult to hold.

Section 12 of the Victorian code provides assistance in performing a more detailed risk assessment including some quantitative elements, particularly for thresholds for awkward postures and repetition and duration (but not weight or force). For example, trunk flexion, lateral flexion, rotation, and neck flexion, lateral flexion or rotation of greater than 20°, and trunk or neck extension of greater than 5°, are all provided as thresholds, as is reaching more than 30 cm from the body. A task is considered to pose a risk, and require control, if movements exceeding these thresholds or other qualitative criteria are performed either repetitively (defined as more than twice per minute) or sustained (defined as more than 30 seconds at a time) AND for long duration (defined as more than 2 hours over a whole shift, or for more than 30 minutes at a time. A task is also considered a risk if it involves "high force actions", even if the force is applied only once, although no quantitative guidance is provided regarding what constitutes a "high force".

The definition provided in the corresponding regulations is:

> "the use of such force that it would be reasonably expected that either most persons in the workforce, or the persons likely to undertake the activity, would have difficulty in undertaking the activity and includes the force required to lift or otherwise handle heavy weights, to push or pull objects which are hard to move, to operate tools designed for one hand if two hands are required and to operate tools which require squeezing of grips that are wide apart"[109]

Section 12.3 of the Victorian code addresses the issue of weight limits, noting the dependence of muscular effort on more than weight alone, and the consequential difficulty in specifying weight limits. However, in Appendix 3 "Further advice on risk assessment and risk control" the Victorian code suggests that other methods for assessing risks may be helpful, providing a table listing a number of tools, as well as strengths and weakness of each. These tools are: Michigan Static Strength Prediction models, 1991 NIOSH Lifting Equation; Snook and Ciriello's tables of maximum acceptable weights and forces, OWAS, RULA and FWAP.

[108] VWA (2000)

[109] Occupational Health and Safety (Manual Handling) Regulations 1999; section 5

United Kingdom - Manual Handling- Guidance on Regulations *2nd ed*
The UK manual handling regulations do not specify threshold limit values, noting:

> "The ergonomic approach shows clearly that such requirements are based on too simple a view of the problem and are likely to lead to incorrect conclusions" [110].

However, Appendix 1 of the UK regulations provides "Manual handling risk assessment detailed assessment guidelines filter" to assist in screening out straightforward cases. The filter is:

> "a set of numerical guidelines developed from data in published scientific literature and on practical experience of assessing risks from manual handling. They are pragmatic, tried and tested; they are not based on any precise scientific formulae. The intention is to set out an approximate boundary within which the load is unlikely to create a risk of injury sufficient to warrant a detailed assessment"[111].

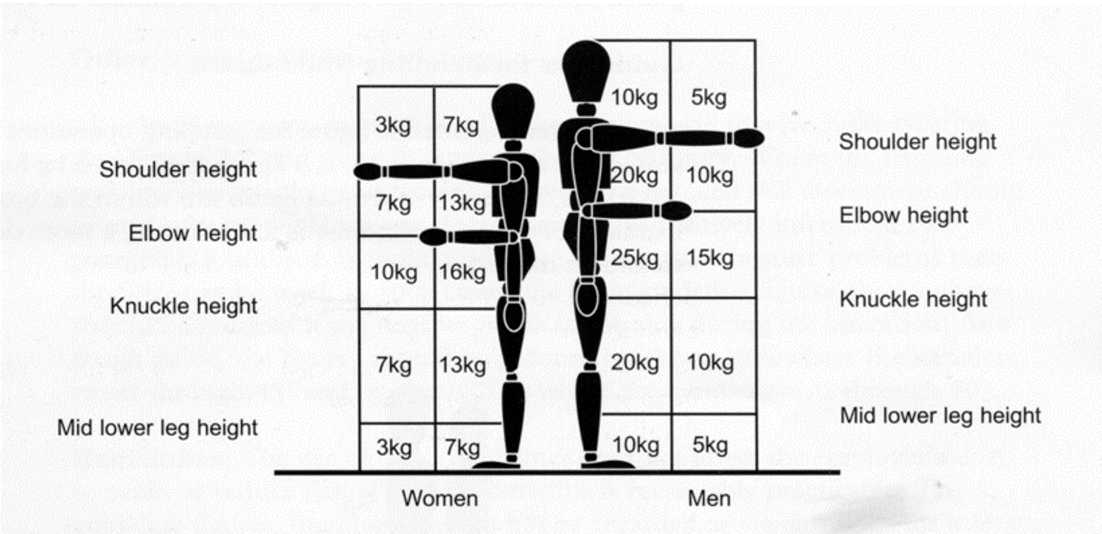

Figure 4: Lifting and lowering guidelines provided in guidance material provided for the UK manual handling regulations[112].

The guidelines assume that the load is easy to grasp, and are for relatively infrequent lifts, up to 30 per hour. The Appendix suggests that the loads should be reduced by 30% if the frequency is 60-120 per hour, by 50% if the frequency is 300-420 per hour, and by 80% if the frequency is 720 per hour. Similar figures are suggested for carrying if the load is carried less than 10 m. Reductions are also suggested where the lifting involves rotation (20% if the handler twists through 90°).

For starting an object moving by pushing or pulling a figure of 250 N is suggested for men and 160 N for women.

[110] HSE (1998) p. 3
[111] HSE (1998) p. 42
[112] HSE (1998) p. 43

The guideline provided for seated handling is 5 kg for men and 3 kg for women if handled within the zone indicated in Figure 5.

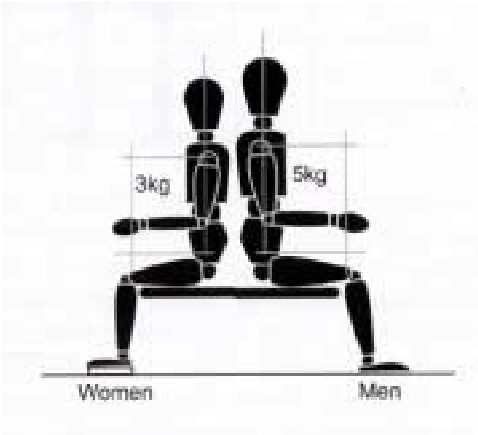

Figure 5: Seated weight limits[113].

No information is provided regarding the derivation of the thresholds provided. The document points out that the figures should not be regarded as weight limits for safe lifting, but rather as an aid to determine where detailed risk assessments are most needed.

United Kingdom - Upper limb disorders in the workplace[114]
This recent document published by the UK HSE provides guidance for UK employers. The document includes a "risk filter" checklist which sets out "an approximate threshold below which the risk of ULDs is likely to be low"[115]. The thresholds provided are qualitative, with the exception of duration, where a threshold of "more than 2 hours total per shift" is provided for exposure to various risk factors. A note suggests however that "the 2 hour period is not a limit and should be applied pragmatically".

The document also provides guidance for completing a risk assessment in the form of more detailed checklists. Qualitative descriptors are provided for many questions, although again, threshold durations (either "2 consecutive hours per work day" or "2 hours total per work day") are provided for exposure to various risk factors (defined qualitatively, eg. Are the wrists/hands/fingers used intensively?). A threshold limit value of 2.8 m/s^2 A(8) is provided for vibration exposure.

The checklist provided for risk assessment also provides notes such as "Remember: the greater the deviation from neutral, the greater the risk"[116] and "Remember to consider how the risk factors interact with each other"[117] without providing guidance as to how this might be achieved.

113 HSE (1998) p. 44
114 HSE (2002)
115 HSE (2002) p.63
116 HSE (2002) p.74
117 HSE (2002) p.82

Sweden – Ergonomics for the prevention of musculoskeletal disorders
The Swedish National Board of Occupational Safety provides "Provisions" on Ergonomics for the Prevention of Musculoskeletal Disorders, and "General Recommendations" on the implementation of these provisions, analogous to regulations and advisory standards/ code of practice.

The General Recommendations section notes that:

> Whether or not a lifting and carrying job is harmful will depend on many simultaneous factors: what is lifted, how the lifting is done. In what environment and who does the lifting or carrying. This makes it very difficult to define an absolute limit value for just one of these factors, such as the maximum permissible weight of a load[118]

Appendix A of the Swedish recommendations provides a "traffic light" model which is intended to provide "an initial indication of whether or not a certain job or operation entails physical loads dangerous to health"[119]. "Red", "Yellow" and "Green" assessments are provided for working conditions including sedentary, standing and walking work postures, defined qualitatively, as well as a quantitative model for lifting work which considers weight and load distance (see Figure 6). Lifting frequency, duration, heights, and other factors are not considered in the model.

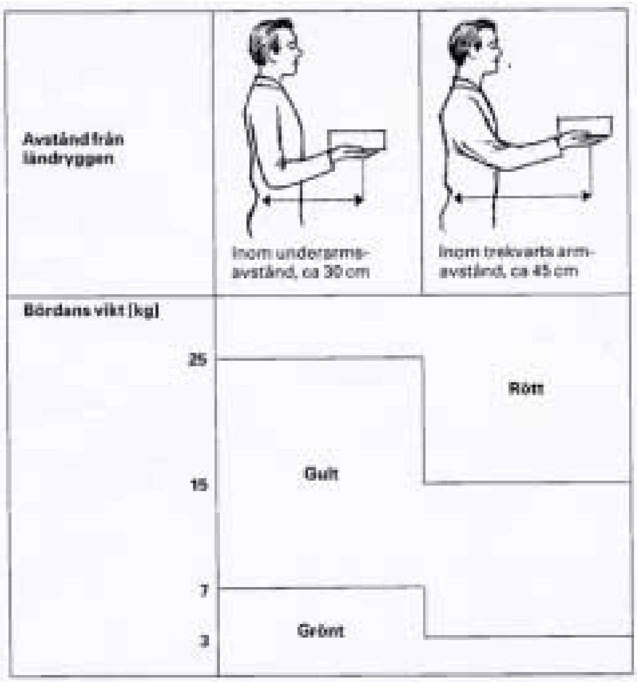

Figure 6: Model for assessment of a symmetrical lifting operation in the standing position, using two hands and under ideal positions[120].

[118] SNBOSH (1998) p. 25
[119] SNBOSH (1998) p. 39
[120] SNBOSH (1998) p. 44

One conclusion drawn from this figure is that handling loads more than 25 kg exceeds the “Red” (Rött) threshold however closely held to the trunk, and for loads held closer than 30 cm, a weight of less than 7 kg is required for the task fall within the “Green” (Grönt) threshold.

Threshold values are also provided for starting, and keeping an object moving by pushing or pulling. Table 1 provides the values for Red, Yellow, and Green cases.

Table 1: Threshold values for symmetric two-handed pushing and pulling with properly designed handles at a suitable height and good ambient conditions[121]

Force (N)	Red	Yellow	Green
Starting	>300	300-150	<150
Continuously	>200	200-100	<100

Quantitative guidance on repetition is provided in that a task is considered to be “Red” if “The work cycle is repeated several times a minute for at least half the shift”. Repetition is “Yellow” if “The work cycle is repeated several times a minutes for at least one hour of the shift *or* many times an hour for at least half the shift”.

In each case, “Red” tasks are considered to require immediate action, “Yellow” tasks require further assessment, and “Green” tasks are acceptable for a majority of employees.

United States Department of Labor Ergonomics Rule

The ill-fated OSHA Ergonomics Rule (which went into effect on Jan 16, 2001 but was rescinded on March 20 of the same year) required employers to assess “problem jobs” in terms of “Ergonomic risk factors” – Force, Repetition, Awkward postures, Static postures, Vibration, Contact stress and Cold. The documentation presenting the proposed rule[122] suggested that although exposure to a single risk factor alone may cause injury, injuries are far more likely when exposure to multiple risk factors occurs and consequently that:

> “it is important that ergonomic risk factors be considered in light of their combined effect in causing or contributing to an MSD”[123]

The OSHA rule did not provide weight limits or threshold limit values for other risk factors with the exception of citing Kilbom’s[124] thresholds for high repetition risk of 2.5 reps/minute for shoulder, 10 reps/min for upper arm, elbow, forearm or wist, and 200 reps/min for fingers.

[121] SNBOSH (1998) p. 46.
[122] Department of Labor (1999). Ergonomics Program; Proposed Rule.
[123] Department of Labor (1999) p. 65809
[124] Kilbom (1994)

OSHA suggested that qualitative assessments of risk exposure was sufficient to satisfy the requirements of the rule, but also cites quantitative methods such as the NIOSH lifting equation, Snook tables, and RULA, and references the NIOSH document “Elements of Ergonomics Programs” as a source of further information for methods of risk assessment. The rule required that the risk assessment and control be undertaken by persons with training in the processes, without specifying the extent of training required[125].

Washington State - Ergonomics Rule

The Washington State rule[126] requires employers who have one or more “caution zone” jobs (as defined semi-quantitatively in WAC 296-62-05105) to analyse these jobs and reduce the hazards below a threshold level defined by either “widely used methods” (eg., Job Strain Index, NIOSH lifting equation, REBA, RULA), or limits provided in Appendix B of the rule. Appendix B provides duration thresholds for quantitatively defined awkward postures, as well as combinations of force, repetition and posture for upper limbs. Threshold values for load weight are also provided as a function of lift height, distance from the trunk, twisting, lift frequency and duration. The maximum weight for a load lifted less frequently than once every five minutes, from a height between knee and waist and held close to the body, and lifted without rotation is 41 kg. Threshold values are also provided for hand-arm vibration. No details are provided regarding the derivation of these thresholds.

[125] Department of Labor (1999) section 1910.925

[126] Washington State (2001) Ergonomics rule. http://www.lni.wa.gov/wisha/regs/ergo2000/ergowac.htm

Appendix C

Manual Tasks Risk Assessment Tool (ManTRA)

Burgess-Limerick, Egeskov, Straker & Pollock (2000)

Scoring matrix and explanatory notes

Manual Tasks Risk Assessment (ManTRA) Explanatory Notes

This Appendix describes the physical risk factors component of an audit tool developed by Robin Burgess-Limerick PhD CPE, School of Human Movement Studies, The University of Queensland; Roxanne Egeskov CPE, Senior Principal Advisor Ergonomics, Division of Workplace Health & Safety, DETIR; Leon Straker, PhD, School of Physiotherapy, Curtin University of Technology, and Clare Pollock, PhD, School of Psychology, Curtin University of Technology. The development of the tool was undertaken as part of a research project funded by Workcover Queensland (QComp) and the National Health and Medical Research Council through a Translational Grant in Injury.

One aim of ManTRA, as originally developed, was to assist DWHS inspectors in auditing workplaces across all industries for compliance with the Queensland Manual Tasks Advisory Standard. A second aim was to make an assessment of the exposure to musculoskeletal risk factors associated with manual tasks in the workplace. For workplace use the assessment should be undertaken by a team including employees who perform the task and staff responsible for manual task risk management.

The physical risk component of the tool combines information about the total time for which a person performs the task in a typical day (exposure) and the typical time for which the task is performed without break (duration) with an assessment, for each of five body regions, of five characteristics of the task (cycle time, force, speed, awkwardness and vibration). The assessment of each characteristic is for the task *as a whole*, rather than individual task elements. The assessment is for a specific person performing a task, rather than people generally. The aim is for the assessor to make a judgement regarding the severity of each characteristic of the task at each region for the task as a whole. The text which corresponds to the numeric codes is provided as a guide only.

The codes for each characteristic describing the task are then combined to assess the extent of exposure to each of the direct risk factors identified in the Queensland Manual Tasks Advisory Standard. The risk factors are assessed independently for each region because a task only needs to overload one body structure to cause injury. A maximum score for exertion for any body region, or a high combined exertion and awkwardness score, indicates a high risk of acute injury; while a high risk of cumulative injury is indicated by the presence of multiple risk factors for a particular body region. Suggested thresholds are provided to aid the user in making judgements about the need for action.

Explanations for each of the codes are provided below.

Total time
Total time refers to the total time which would be spent performing the task on a typical day. The code will be the same for each body region.

Total time

1	2	3	4	5
0-2 hours/day	2-4 hours/day	4-6 hours/day	6-8 hours/day	8-10 hours/day

Repetition
Tasks which involve short cycle time and prolonged duration are considered to be a risk factor because of the inevitable loading of the same tissues during the task. Tasks performed for a very long duration without interruption (> 2 hr) are similarly a risk, regardless of the cycle duration. Reduced risk is associated with tasks involving longer cycle times and shorter task duration. Cycle time and task duration are first assessed independently, and then a combined score for repetition is allocated.

Cycle time refers to the duration of task which is performed more than once without interruption. The cycle time code may vary between body regions. If a task is performed once only at any time without repetition then the code for cycle time is minimum (1). *Duration is defined as the typical length of time for which repetitions of the task are performed without any rest break or substantial interruption by any other task*. The duration code will be the same for all regions for any particular task. Cycle time and duration codes are combined to give an overall score for repetition using the key below.

Duration

1	2	3	4	5
< 10 minutes	10 min - 30 min	30 min - 1 hr	1 hr - 2 hr	> 2 hr

Cycle time

1	2	3	4	5
> 5 minutes	1 – 5 minute	30 s - 1 min	10 s - 30 s	< 10 s

Repetition Risk Factor

			Duration		
Cycle Time	***1***	***2***	***3***	***4***	***5***
1	1	1	2	3	4
2	1	2	3	4	4
3	2	3	3	4	4
4	3	3	4	4	5
5	3	4	4	5	5

Force
The exertion risk factor identified in the advisory standard has been expanded in ManTRA to separate force *per se*, from the speed of movement. Exertion in this audit tool requires an assessment of the force exerted within each region during the task relative to the maximal force which can be exerted. Note that the assessment should be made relative to the strength capability of the region rather than absolute force ie, a relatively small force may still require a "maximal" rating if exerted by a small muscle group (eg., fingers) but not if exerted by the lower limbs. The assessment of force is relative to the capability of the person performing the task. The force required should be rated independently of the duration of the exertion, that is, a short task which involves moderate force in the region is rated the same as a longer task. (Duration is a separate risk factor). *A maximum force score corresponds to the maximum force possible*, if greater force could have been exerted, the score should be reduced accordingly.

Force

1	2	3	4	5
Minimal force		Moderate force		Maximal force

Speed
The speed of movement has been identified as a separate risk factor. The least risk arises when a task involves slow to moderately paced movements. Tasks which involve primarily static application of force in the region contribute to the risk of musculoskeletal injury. Tasks involving fast movements, and especially those involving rapid accelerations and decelerations constitute higher risks again. The assessment should be of the overall task eg., a tasks which involves mostly slow movements with some fast elements should be rated as moderately paced. However, *the code "3" is reserved for predominantly static tasks only.*

Speed

1	2	3	4	5
Slow movements	Moderately paced	Little or no movement– static posture	Fast and smooth movements	Fast, jerky movements

Exertion Risk Factor
Codes for force and speed are combined to give an overall score for exertion using the following key.

			Force		
Speed	***1***	***2***	***3***	***4***	***5***
1	1	1	2	3	4
2	1	2	3	4	4
3	2	3	4	4	5
4	2	3	4	5	5
5	3	4	5	5	5

Awkwardness

Awkwardness is difficult to define independently of specific joints, but typically postures which involve significant deviations from the mid range of movement constitute an increased risk of injury. Higher risk occurs when the deviation occurs in combinations, eg, trunk flexion combined with trunk rotation, or wrist extension and ulnar deviation. As before, the rating is for the task as a whole and the rating should be adjusted to reflect the proportion of time spent in postures of varying awkwardness. Here especially, the text is a guide only and judgement is required.

Awkwardness

1	2	3	4	5
All postures close to neutral	Moderate deviations from neutral in one direction only	Moderate deviations in more than one direction	Near end range of motion posture in one direction	Near end range of motion in more than one direction

Vibration

Exposure to whole body vibration in addition to other risk factors contributes to increased injury, particularly in the back and neck, and lower limbs. Peripheral vibration, on the other hand, is primarily a risk factor implicated in upper limb disorders. Consequently an assessment of the *severity of whole body vibration is requested for lower limbs, back, and neck regions*, while the severity of *peripheral vibration should be indicated for shoulder/arm and wrist/hand regions.* The rating is for the whole task and the score should be adjusted for duration of exposure as a proportion of the task.

Vibration (Whole body or Peripheral)

1	2	3	4	5
None	Minimal	Moderate amplitude	Large amplitude	Severe amplitude

Suggested thresholds for further action

After combining the force and speed codes to obtain a rating of the exertion risk factor, and combining the cycle time and duration to obtain a repetition risk, a cumulative risk score for each region should be calculated as the sum of codes for:

Total time + repetition + exertion + awkwardness + vibration

That is, the cumulative risk score is the sum of the scores in the unshaded columns. This yields a possible range of scores between 5 and 25.

One aim of the audit tool was to assist inspectors make a determination regarding compliance of a task with the Manual Tasks Advisory Standard. It was suggested that further action may be indicated if for any body region**:**

- *the combined risk factor for exertion is 5,*
- *the sum of exertion and awkwardness is 8 or greater; or*
- *the combined cumulative risk scores is 15 or greater*

These threshold values provide guidance in the prioritisation of tasks for control, and the profile of risk factor ratings should be utilised in provided advice regarding aspects of the task to which controls should be targeted.

Manual Tasks Risk Assessment tool (ManTRA) Scoring Matrix

			Task Codes							CumulativeRisk
Body Region	Total time	Duration	Cycle time	Repetition Risk	Force	Speed	Exertion Risk	Awkwardness	Vibration	
Lower Limbs										
Back										
Neck										
Shoulder/ Arm										
Wrist / Hand										

Cumulative risk is the sum of unshaded cells.

Codes

Total time

1	2	3	4	5
0-2 hours/day	2-4 hours/day	4-6 hours/day	6-8 hours/day	> 8 hours/day

Duration of continuous performance

1	2	3	4	5
< 10 minutes	10 min - 30 min	30 min - 1 hr	1 hr - 2 hr	> 2 hr

Cycle time

1	2	3	4	5
> 5 minutes	1 – 5 minute	30 s - 1 min	10 s - 30 s	< 10 s

Force

1	2	3	4	5
Minimal force		Moderate force		Maximal force

Speed

1	2	3	4	5
Slow movements	Moderately paced	Little or no movement – static posture	Fast and smooth movements	Fast, jerky movements

Awkwardness

1	2	3	4	5
All postures close to neutral	Moderate deviations from neutral in one direction only	Moderate deviations in more than one direction	Near end range of motion posture in one direction	Near end range of motion in more than one direction

Vibration **(Whole body or Peripheral)**

1	2	3	4	5
None	Minimal	Moderate	Large amplitude	Severe amplitude

Scoring Keys for Repetition & Exertion

Scoring key for Repetition

			Duration		
Cycle Time	***1***	***2***	***3***	***4***	***5***
1	1	1	2	3	4
2	1	2	3	4	4
3	2	3	3	4	4
4	3	3	4	4	5
5	3	4	4	5	5

Scoring key for Exertion

			Force		
Speed	***1***	***2***	***3***	***4***	***5***
1	1	1	2	3	4
2	1	2	3	4	4
3	2	3	4	4	5
4	2	3	4	5	5
5	3	4	5	5	5

Action may be indicated if, for any region, the Exertion risk factor is 5, the sum of exertion and awkwardness is 8 or greater, or the cumulative risk is 15 or greater

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