CHAPTER 8

Ergonomics Evaluation Methods

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THIS CHAPTER PROVIDES:

- Guidelines for conducting data collection and choosing a research approach.
- Heuristic evaluation.

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- Various posture analysis methods; REBA, RULA and OWAS.
- Biomechanical assessment methods; NIOSH, Liberty Mutual materials handling tables.
- Combined methods; KIM.
- Standards and provisions from different countries.

WHY DO I NEED TO KNOW THIS AS AN ENGINEER?

Once we have a clear idea of what goes on in a workplace when workers perform tasks, we may be able to use our knowledge of what is beneficial or harmful to human work abilities to determine where the improvement potentials are. But analysing the risks and improvement potentials based on that knowledge may get complicated, easy to over- or understate, and difficult to communicate to other stakeholders who are not educated about the human body's needs and capabilities. In other words, a reliable shortcut is needed to help us decide what to target in improvement work – preferably in a way that simplifies and quantifies the risk levels to make comparisons easier.

In this chapter a number of analytical methods for assessing (mainly physical) ergonomics will be added to your "toolbox". This enables you to evaluate workplaces with respect to one or more of the physical loading factors mentioned in Chapter 3 (posture, forces and/or time), sometimes in combination with other work environment aspects such as those mentioned in Chapter 11. Most of the described ergonomics evaluation methods help you structure your analysis and prioritize which problems to target first by identifying the greatest risks for physical injury, ranking them in order of severity, and indicating which body segments are at risk. This structure of assessment makes it easier to communicate your decision basis to other stakeholders and justify particular interventions that target physical ergonomics root causes.

WHICH ROLES BENEFIT FROM THIS KNOWLEDGE?

Both the *system performance improver* and the *work environment/safety specialist* need knowledge of the methods presented here in order to communicate effectively with other stakeholders about physical loading risks that are present in the workplace. The eventual translation of risk into "severity levels" (often *red/yellow/green* classifications) is helpful in communications with management and other stakeholders tracking KPIs, but being able to arrive at these classifications requires solid knowledge of how to appropriately choose a method that captures the appropriate risk perspective. These roles may also find themselves communicating with medical or health and safety professionals with a more individual-risk focused perspective. The engineer with knowledge of these methods is given a platform for discussing how risk elements associated with particular body segment loading can be targeted.

The use of established, documented methods is important when conducting any assessment, as it ensures that analyses are conducted in a standardized, repeatable way. So should someone else carry out the same analysis at a later point in time, it is possible to fairly compare the results of both studies in a meaningful way.

A number of methods exist which enable us to study, analyse and evaluate humans while they are carrying out work tasks. Combining such methods with knowledge about the anatomical structure of the body and how it reacts to loading enables us to design effective and healthy workplaces. This chapter will introduce a number of useful methods and guidelines to evaluate whether humans are at risk when performing work tasks and interacting with their surrounding environment. Most methods also provide a guide for prioritization, helping the analyst determine which problems to address first.

8.1. Heuristic evaluation (HE)

One rough inspection or "checklist" method that enables general ergonomics issues to be identified is a *heuristic evaluation*. Heuristics can be explained as "rules of thumb" or "shortcuts" to decisions, based on conventional knowledge. With this method, a workplace or work tasks are evaluated according to a set of accepted principles, based on theoretical knowledge of human abilities and physical limitations, alongside past experience of how a design should be to work effectively. Deviations or causes for concern are noted and prioritized. Using a set of heuristics that have been predetermined before the study is known as a *structured* heuristic evaluation, but there is also some benefit from taking an *unstructured* approach and making up a list of heuristics as you go along during the evaluation. In the case of an unstructured approach, a high degree of theoretical knowledge is required on the part of the analyst, in order to conduct a meaningful and valuable study. For this reason, heuristic evaluations demand the participation of an expert to be accepted as reliable. Examples of common heuristics to consider when analysing a workstation are:

- No bending of the neck backwards.
- Pinching grasps should be avoided.
- Bending and twisting of the spine should be avoided.
- For heavier work, a working height of 100–250 mm below elbow height is recommended.
- For light work, a working height of 50–100 mm below elbow height is recommended.
- For push buttons, a height between elbow and shoulder is recommended.
- Lifting should be carried out close to the body.
- Adaptation to anthropometric variation (different body sizes) should be possible.

To conduct a heuristics evaluation the following procedure should be followed:

1. **Select heuristics to evaluate with**
   - Use existing (structured evaluation)
   - Create your own (structured evaluation)
   - Unstructured evaluation
2. **Evaluate the design based on the heuristics**
   - Note deviations from heuristics

- Explain why something is a problem (with respect to the heuristics) – simply identifying a problem is not enough
- Use task analysis as a base (for example, HTA)

3. **Assemble deviations and identify problems**
   If there is more than one evaluator this is done jointly, and a protocol created.
4. **The severity of the problems and deficiencies are assessed (if possible):**
   0 = Not an ergonomic problem.
   1 = Inconvenience problem; does not need to be fixed unless extra time is available.
   2 = Minor ergonomic problem; fixing should be given lower priority.
   3 = Major ergonomic problem; important to fix, high priority.
   4 = Very serious ergonomic problem; need to be fixed, high risk of injury.
5. **Reporting of results**
   - Compile into a protocol
   - Show result with task analysis

When showing the result on an HTA, it can be beneficial to use a colour-coded system to highlight the severity of the problems, hence indicating a priority order for design changes. For example, the HTA in Figure 8.1 shows areas for concern based on a heuristics evaluation of the task of changing tyres on a car.

To ensure this method is carried out effectively, it is important to be aware of both its strengths and weaknesses. While it is a fast, resource-efficient method that is simple to carry out, it is also limited in value due to its subjective nature, limited scope and somewhat unsystematic evaluation approach.

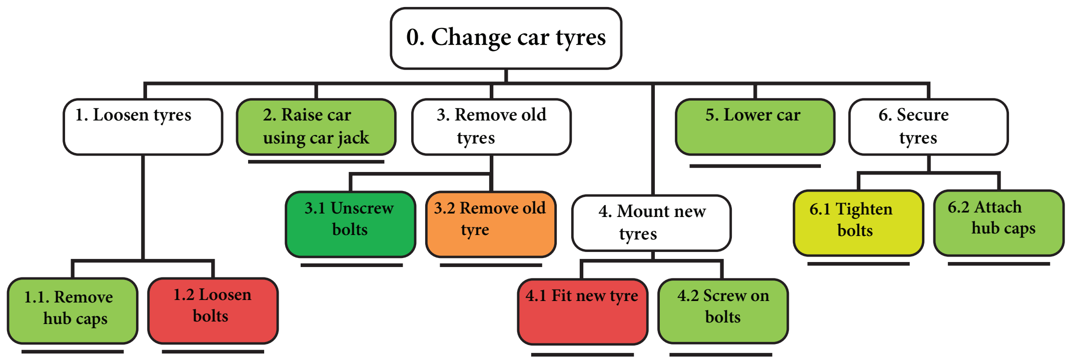


Figure 8.1: HTA demonstrating severity of issues identified during HE, when changing car tyres.
Illustration by C. Berlin.

Where the colour levels indicate:
0 = No Problem
1 = Inconvenience
2 = **Minor** ergonomic problem
3 = **Major** ergonomic problem
4 = **Very** serious ergonomic problem

8.2. Methods for evaluating physical loading

A number of different established methods exist for assessing physical load. These methods fall under three broad categories:

- Posture-based analysis
- Biomechanics-based analysis
- Analysis based on a combination of environmental factors

Table 8.1 provides a summary of some of these methods, describing their main function and which category they belong to. There are many, many more ergonomics evaluation methods available, but this list aims to present a variety across the categories mentioned. To give detailed instructions for each method would make this book very cumbersome, and it is often best to use the source materials for this purpose, so each method description in this chapter also provides links to instruction sheets for each method, as made publicly available.

8.3. Posture-based analysis

Having provided an anatomical basis for understanding the capabilities of the human body in earlier chapters, we will now go onto discuss posture-based methods for studying work tasks from a physical ergonomics perspective. Posture-based ergonomics evaluation methods use point-based systems to rank identified areas of concern. Typically, the more the body deviates from the neutral standing position, the worse the working posture is, thus resulting in a higher score. The selected methods presented here are quick and simple to conduct and are based purely on observations, making them somewhat vulnerable to interpretation. By looking at different regions of the body and joint angles, the loads experienced by the body are ranked on a pre-determined scale of risk severity.

Generally, posture-based observation methods are *screening tools,* meant to give a risk estimation for system designers to prioritize which risk factors to address first; generally the point is to eliminate causes of high rating points as a first step. If the screenings return results indicating some uncertainty as to the risk level, more in-depth analyses may be recommended, perhaps using a different risk assessment tool. While these methods are quick and simple ways to evaluate posture, they are somewhat limited as they don't always consider time exposure or accumulating loads, and are subjective due to the element of observation. Generally, the same method should be used before and after a design change to monitor the impacts of design changes, to see if sufficient posture improvements have been made according to the same set of posture assessment criteria.

RULA (Rapid Upper Limb Assessment)

RULA and REBA are two similar methods that can be used to quickly screen and identify harmful postures. RULA (McAtamney & Corlett, 1993) is more suited to hand-arm intensive work, having been developed to study sitting assembly work in textile confectionery industry, while REBA (Hignett & McAtamney, 2000) covers whole-body intensive work, as it was developed in a hospital/healthcare context. Both methods focus on one specific posture that occurs during the work tasks. This posture

Table 8.1: Summary of physical load assessment methods and associated resources for manuals, worksheets etc.

Method	Purpose and online resources for manuals and worksheets	Postural analysis	Materials handling tasks	Additional aspects (time, space, intensity, speed, etc.)
RULA (Rapid Upper Limb Assessment)	Upper body & limb assessment, screening of postures **Introduction, paper- and spreadsheet-based worksheets:** http://ergo.human.cornell.edu/ahRULA.html	×		
REBA (Rapid Entire Body Assessment)	Whole-body posture analysis, screening of postures **Introduction, paper- and spreadsheet-based worksheets:** http://ergo.human.cornell.edu/ahREBA.html	×		
OWAS (Ovako Working Posture Analysing System)	Whole body posture analysis, screening of postures over time **Manual:** Available as a handbook/training publication, see Reference list (Louhevaara and Suurnäkki, 1992)	×		×
NIOSH Lifting Equation	To identify whether a lifting load is acceptable for workers **Applications Manual for the Revised NIOSH Lifting Equation including tables of multipliers:** http://www.cdc.gov/niosh/docs/94-110/ and http://www.ergonomics.com.au/use-revised-niosh-equation/		×	
Liberty Mutual manual materials handling tables	To identify the portion of a specified male or female population that should be able to lift, lower, carry, push or pull as part of their daily work, without risks for MSDs **Tables:** https://libertymmhtables.libertymutual.com/CM_LMTablesWeb/taskSelection.do?action=initTaskSelection		×	

JSI **(Job Strain Index)**	Assessment of risk for upper extremity disorders, particularly focused on repetitive tasks **Method description and worksheets:** http://ergo.human.cornell.edu/ahJSI.html and http://www.theergonomicscenter.com/graphics/ErgoAnalysis%20Software/Strain%20Index.pdf	×		×
KIM **(Key Indicator Method)**	To identify level of risk associated with manual material handling tasks – exists in three specific forms for different materials handling cases **Lifting – Holding – Carrying:** http://www.beswic.be/en/topics/msds/slic/handlingloads/29.htm **Pushing – Pulling:** http://www.beswic.be/en/topics/msds/slic/handlingloads/19.htm/30.htm **Manual Handling Operations:** http://www.baua.de/de/Themen-von-A-Z/Physische-Belastung/pdf/KIM-manual-handling-2.pdf?__blob=publicationFile&v=4		×	×
EAWS (Ergonomic Assessment Worksheet)	Screening worksheet developed by the MTM (methods-time measurement) community to evaluate ergonomic risk exposure aligned with predetermined time standards **Method description and worksheets:** http://mtm-international.org/risk-screening-the-ergonomic-assessment-work-sheet-eaws/	×	×	×
RAMP **(Risk Assessment and Management tool for manual handling Proactively)**	*RAMP I* **Checklist for screening physical risks for manual handling** https://www.ramp.proj.kth.se/		×	x
	RAMP II **In-depth analysis for assessment of physical risks for manual handling** https://www.ramp.proj.kth.se/	×	×	×
HARM (Hand Arm Risk-assessment Method)	Hand- and arm-focused analysis method to identify and screen repetitive tasks **Manual and worksheets:** https://www.fysiekebelastingbeoordelen.tno.nl/download/HARM_Manual_paper-based_harm.pdf	×		×

is generally identified through observations and discussions with the worker. Generally, postures that occur frequently, last for a prolonged period of time, involve large forces or muscular activity, cause discomfort, or are considered to be extreme are the ones typically selected for analysis. During an assessment, the whole task is observed and key postures of interest are identified. These data points can then be captured visually (e.g. filmed, photographed or observed) enabling a RULA score to be calculated using the RULA assessment form. For conditions that are considered to worsen the posture, additional "penalty" points are added. The final score is used as an indication to show how soon it is necessary to do something about the observed posture. In a RULA analysis, the positions of six different body regions are considered: upper arm, forearm, wrists, neck, trunk (upper torso) and legs. Based on the deviations of each body part from the "neutral" position, the weight of any loads, and the nature of movements (static or dynamic), an overall score is calculated. This final score between 1–7 corresponds to a ranking, which indicates to the analyst whether the posture presents an injury risk. It is possible to conduct a RULA analysis within simulation software (this is discussed in more detail in Chapter 9); despite being older than REBA, RULA is more commonly found as an evaluation tool in simulation software.

Worksheets for paper-based RULA evaluations (in metric measures) are available at the link in Table 8.2.

REBA (Rapid Entire Body Assessment)

REBA (Hignett & McAtamney, 2000) is a similar method for evaluating body postures during work tasks, but unlike RULA it focuses on whole-body intensive work. Similarly to RULA, one specific posture that occurs during the work task is analysed to provide an overall score. A REBA analysis considers the same six body regions as RULA, but it goes one step further by also taking couplings and grips into consideration. Points are added for conditions that worsen the nature of the posture, and points can also be subtracted if something contributes towards lessening the loading impact of the posture (such as gravity-assisted postures). The final score between 1–15 is calculated using the REBA assessment form.

Worksheets for paper-based REBA evaluations (in metric measures) are available at the link in Table 8.2.

KEY CONSIDERATIONS FOR RULA AND REBA ANALYSIS

When conducting RULA and REBA the following points should be kept in mind:

- Is the posture caused by the environment (workplace) or materials being handled?
- Does the selected posture affect both tall and short workers?
- Did you assume that this posture is transient (a changing movement)?
- How often does this posture occur?
- What kind of strength does the position require?
- Would training help in eliminating the posture?

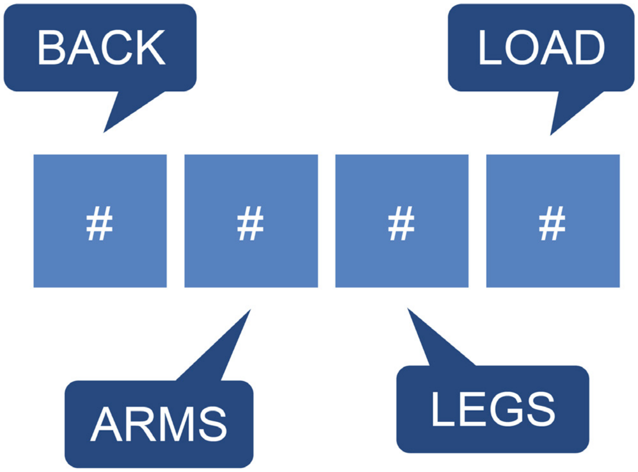


Figure 8.2: OWAS Score – each digit represents a posture or load assessment.
Illustration by C. Berlin.

OWAS (Ovako Working Posture Analysing System)

OWAS, short for Ovako Working Posture Analysing System, is somewhat similar to REBA and RULA in that it provides a figure indicating how harmful a posture is (Louhevaara and Suurnäkki, 1992). Since it originated in the steel industry, the method was initially designed with heavy lifting in mind. The analysis result is a four-digit score describing posture (Figure 8.2), where the first value is concerned with the back, the second the arms, the third the legs and the fourth weight/external load. The end result highlights the areas where most of the riskiest work postures appear. The complete process necessary to carry out an OWAS analysis is described in Louhevaara and Suurnäkki (1992).

HARM (Hand Arm Risk-assessment Method)

HARM (Douwes and de Kraker, 2014) is a method developed by researchers at the Dutch institute TNO (the Netherlands Organisation for Applied Scientific Research), specifically tailored to analysing risks for MSDs in the hand and arm, and it takes into account both posture of the arms, wrists, neck and head, and also time aspects (including repetitiveness) and forces. The method exists as HARM1.0 (Douwes and de Kraker, 2014) and the updated HARM 2.0 (TNO, 2012) with reduces the relative weight of task duration, simplifies the force categories and includes some clarifications and changes to the instructions and the manual.

8.4. Biomechanics-based analysis

Ergonomic evaluation methods that utilise biomechanical calculations also exist. These methods tend to be based on the evaluation of work tasks that involve moving a load from one place to another by pushing, pulling, carrying, lowering or lifting it. Compared to observational posture-based analysis methods, they take longer to carry out and provide a strictly defined, more numerical result.

Liberty Mutual manual materials handling tables

Based on the initial research work presented by Dr Stover Snook and Dr Vincent Ciriello initiated in 1978 on materials handling, Liberty Mutual (an American insurance company) established an analysis tool to assess lifting, lowering, pushing, pulling and carrying tasks in the workplace (Snook & Ciriello, 1991). Given the costs associated with back disabilities and reduced productivity resulting from manual materials handling tasks, the tables provide criteria levels at which lifting can be judged as suitable or unsuitable for a well-defined working population. It is considered an objective risk assessment, in terms of being statistically backed. Since it is based originally on the work of Dr Snook, this method is also sometime referred to as "Snook's Lifting Recommendation" or "The Snook Tables".

A number of different tables provide information about both the male and female population, their capabilities for lifting, lowering, pushing, pulling and carrying. The tables can be used to identify the portion of the population that should be able to conduct such tasks as part of their daily work. The relevant table for the population and task at hand is selected, and the resulting maximum criteria value provides aid in modifying or redesigning the work task, to reduce or eliminate injury risk.

This method takes into consideration the vertical height of the item to be lifted, its weight, hand distance, hand height before and after the object has been lifted, frequency of tasks, and the distance it should be pulled, pushed or carried.

The updated tables and materials are accessible from the link in Table 8.2.

NIOSH lifting equation

This method, based on work conducted at the National Institute of Occupational Safety and Health (NIOSH) in America, is used to calculate whether lifting a load is acceptable (Waters et al, 1993; see Figure 8.3), using an equation which considers:

- Horizontal distance of the load from the worker
- Vertical height of the lift
- Vertical displacement during the lift
- Angle of symmetry between the mid-plane of the body and the direction of lift
- Frequency, duration of lifting
- Coupling between the worker's hand and the object.

By using a load constant of 23 kg, or 50 lbs (considered the maximum lifting weight permissible even under the best possible lifting circumstances) multiplied by factors that are ≤ 1, it is possible to calculate the RWL (Recommended Weight Limit) that can be handled by the majority of healthy people[1] during the working day:

$$\mathbf{RWL = LC \cdot HM \cdot VM \cdot DM \cdot AM \cdot FM \cdot CM}$$

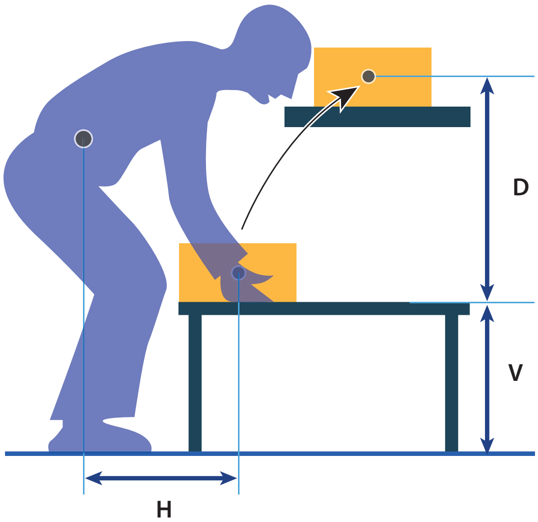


Figure 8.3: NIOSH Equation Schematic.
Illustration by C. Berlin, based on Bohgard (2009).

The Lifting Index (LI) is a related indicator that is calculated as follows:

$$\mathbf{LI = L/RWL}$$

...where LI > 1 indicates an increased injury risk.
RWL = Recommended Lifting Weight
LI = Lifting Index
LC = Load Constant = 23 kg
HM = Horizontal Multiplier
VM = Vertical Multiplier
DM = Distance Multiplier
AM = Asymmetric Multiplier
FM = Frequency Multiplier
CM = Coupling Multiplier
L = Load Weight (the proposed weight)

Each of the multipliers is a decimal between 0 and 1, which decrease the LC when multiplied with it. These multiples are fetched from tables in the appendix of the manual for the revised NIOSH lifting equation (Waters et al., 1994).

It is important to note that there are a number of instances when the NIOSH lifting equation should *not* be used:

- When lifting with one hand
- When lifting work occurs for longer than an 8-hour shift
- When kneeling or sitting

- In a cramped space
- When lifting unstable objects (liquid containers, half-full boxes, etc.)
- When simultaneously carrying, pulling and pushing
- When using a wheelbarrow or shovel
- For quick lifting (high acceleration)
- On slippery floors
- In unfavourable environmental conditions, such as below 19°C, over 26°C or high humidity

The Applications Manual for the Revised NIOSH Lifting Equation including tables of multipliers are available at the link in Table 8.2.

8.5. Multi-aspect methods

JSI (Job Strain Index)

The Job Strain Index is another method used to identify injury risks during work tasks, but it is specifically focused on the upper extremities (wrist and hands) and is particularly beneficial when analysing repetitive jobs (Moore and Garg, 1995). This method takes in account the following aspects:

- Intensity of the exertion (IE)
- Duration of the exertion (DE)
- Efforts per minute (EM)
- Posture (HWP)
- Speed of work (SW)
- Duration of task per day (DD)

Each of the six factors are weighted based on tables using biomechanical, physiological, epidemiological and psychological criteria, and a final score is achieved by multiplying all the factors together:

$$\mathbf{JSI = IE \times DE \times EM \times HWP \times SW \times DD}$$

The resulting score indicates the risk of developing a distal upper extremity disorder. It should also be noted that this method has a degree of subjectivity, as not all the factors can be explicitly measured. This method does not consider tasks involving vibrations or contact stress, which will obviously have a significant impact on the worker over time.

The method description and worksheets are available at the links in Table 8.2.

KIM (Key Indicator Method)

This analysis method was developed by the German Federal Institute for Occupational Safety and Health (2012) and is a screening method targeted at the manual handling of loads. There are three different variants of KIM: one for analysing work tasks and activities involving manual handling operations (MHO), another one for pulling and pushing (PP), and a third for lifting, holding and carrying (LHC). A series of rating points for a number of attributes including time, load, posture and working conditions (including work environment) are used to determine an overall score, which can then be checked against an established scale to determine the severity of the risk presented to the worker. A final score is achieved by adding the load, posture and working conditions ratings and multiplying the sum by the time rating. Rating points for each attribute are then determined by observing the task and selecting the most applicable characteristic from a series of predetermined tables.

The work templates for the three variants of the KIM method are available at the links in Table 8.2.

EAWS (Ergonomic Assessment Worksheet)

The Ergonomic Assessment Worksheet, EAWS, is a quick screening tool developed by the International MTM Directorate (IMD, 2015), an international interest organization for Predetermined Time Systems (which have a historically significant presence in the industrial engineering discipline). EAWS covers four risk areas: body postures, action forces, manual materials handling and upper limbs (with focus on high frequency). In keeping with the MTM emphasis on standardization, the method's acceptability criteria are aligned with several international standards, including CEN and ISO. The worksheet output is a green-yellow-red acceptability rating, based on a cumulative point scale.

The method description and worksheets are available at the links in Table 8.2.

RAMP (Risk Assessment and Management tool for manual handling Proactively)

RAMP is an observation-based method developed at Sweden's KTH Royal Institute of Technology for analysing workplaces for risks of MSDs (Lind et al., 2014; Lind, 2015; Rose, 2014). The method exists in the form of a simplified checklist for initial screening called RAMP I, where the analyst answers Yes or No to the occurrence of a number of risk types (covering the areas of postures, repetitive movements, lifting, pushing/pulling, influencing factors, physical strain and perceived discomfort), or as RAMP II, a refined analysis module to be used when the RAMP I analysis identifies risks that are uncertain in their cause or severity and require further analysis. The output from RAMP I is a colour-scale rating of green (low risk), grey (investigate further) and red (high risk). The output from RAMP II is a colour-scale rating of green (low risk), yellow (risk) and red (high risk), along with a sum of scores to help determine the prioritization of what to address first. Due to the inclusion of perceived operator discomfort, it is necessary to have an experienced operator (or more, to include variations in their work) to observe and talk to when analysing the task.

8.6. Standards, legal provisions and guidelines

Ergonomists and work designers in many countries use standards, guidelines and legal provisions to ensure that a workplace does not harm the workforce – sometimes these guideline documents have a powerful impact on achieving implementation of good workplace standards, as the legal status and recognition of the guidelines may be the only thing that will convince the management to take action to benefit the workers' well-being. Some countries have a strong tradition and established institutions continually release and update workplace guidelines that regulate the responsibilities of organizations and employees to provide and maintain a safe and healthy workplace. Table 8.3 summarizes a selection of national and international documents that guide and regulate the design of

Table 8.3: Examples of national and international/provincial codes, standards and guidelines primarily aimed at preventing work-related MSDs. Collected by the ILO and IEA for different countries (taken from Niu, 2010 p. 750).

Country	Document
Australia	• National Code of Practice for Manual Handling [NOHCS: 2005(1990)] • National Code of Practice for the Prevention of Occupational Overuse Syndrome [NOHSC: 2013 (1994)] • Manual Tasks Advisory Standard 2000 – Queensland • Code of Practice for Manual Handling 2000 – Victoria
China	• Law on Prevention and Control of Occupational Diseases (Article 13 of Chapter II Preliminary Prevention). 2002 • Occupational exposure limits for hand-transmitted vibration in the workplace (GBZ 2.2-2007), Measurement methods (GBZ/T 189.9), and Diagnostic criteria of occupational hand-arm vibration disease (GBZ 7) • Hygienic Standards for the Design of Industrial Enterprises (GBZ1) on workplace lighting and illumination • Guidelines for occupational hazards prevention and control (GBZ/T 211-2008)
European Community	• Directive 89/391 Introduction of measures to encourage improvements in the safety and health of workers at work • Directive 90/269/EEC Minimum health and safety requirements for the manual handling of loads where there is a risk particularly of back injuries to workers • Directive 2002/44/EC Minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration).
ISO	• ISO 11228-1 Ergonomics – Manual Handing – Part 1: Lifting and Carrying • ISO 11226 Ergonomics – Evaluation of static working postures • ISO/FDIS 6385:2003 Ergonomic Principles in the Design of Work Systems
Japan	• Guidelines on the prevention of lumbago in the workplace (1994).
Netherlands	• Working Conditions Act 1998
New Zealand	• Code of Practice for Manual Handling • Approved Code of Practice for the Use of Visual Display Units in the Place of Work • Occupational Overuse Syndrome (OOS) – Guidelines for prevention and management (1991) and Occupational Overuse Syndrome. Checklists for the evaluation of work (1991)
Norway	• Act Relating to Worker Protection and Working Environment (2003)
South Africa	• Occupational Health and Safety Act 1993
Spain	• Royal Decree 487/1997 Minimum health and safety provision relating to manual load handling involving risks for workers, particularly to the dorsolumbar region and the associated technical guide for the evaluation and prevention of risks associated with manual load handling. • Royal decree 488/1997 Minimum health and safety dispositions relating to work with equipment fitted with visual display units and the associated technical guide for the evaluation and prevention of risks associated with the use of equipment with visual display units.

Country	Document
Sweden	• AFS 2001:1 – Provisions of the Swedish Work Environment Authority on Systematic Work Environment Management, together with General Recommendations on the Implementation of the Provisions. • AFS 1998:1 – Provisions of the Swedish National Board of Occupational Safety and Health on Ergonomics for the Prevention of Musculoskeletal Disorders, together with the Board's General Recommendations on the Implementation of the Provisions
UK	• The Manual Handling Operations Regulations 1992 • The Health and Safety (Display Screen Equipment) Regulations 1992. • Upper limb disorders in the workplace. HSE, 2002 • Aching arms (or RSI) in small businesses, HSE, 2003 • Manual Handling Assessment Charts. HSE, 2003
USA	• OSHA, 2003: Ergonomics for the Prevention of Musculoskeletal Disorders. Guidelines for Poultry Processing. • NIOSH: Simple Solutions: Ergonomics For Farm Workers, 2001 • California Dept of Industrial Relations, 1999: Easy Ergonomics. A Practical Approach for Improving the Workplace • California Dept of Industrial Relations, 2000: Fitting the Task to the Person: Ergonomics for Very Small Businesses • State of Washington, Dept of Labor: WAC 296-62-051. Ergonomics • State of Washington, Dept of Labor: Fitting the Job to the Worker: An Ergonomics Program Guideline

work environments, with a main goal to prevent MSDs. The list was compiled in 2010 (Niu, 2010) as a collaboration between the International Labour Organization (ILO) and the International Ergonomics Association (IEA), and is shown as an overview – however, it is important to follow the updates of governing bodies for workplace health and safety, since they continually update requirements and guidelines. As an example, this book takes a closer look at the Swedish Work Environment Authority's most recent MSD-focused legal provisions.

8.7. Example: Swedish AFS provisions

The Swedish Work Environment Authority (*Arbetsmiljöverket*), formerly known as the Swedish National Board of Occupational Safety and Health (*Arbetarskyddstyrelsen*), is a legal entity in Sweden that works continually with releasing, renewing, amending and combining the legal guidelines, called *provisions*, for designing safe and healthy workplaces. All of these are enactments and updates of the Work Environment Act, which was established in 1977. The provisions are part of the Statute Book (AFS, *Arbetarskyddstyrelsens FörfattningsSamling*) and cover a very wide range of specific guidelines, ranging from physical loading and materials handling to chemical hazard restrictions, sector-specific guidelines, exposure limit values, psychosocial work environment and how to carry out systematic

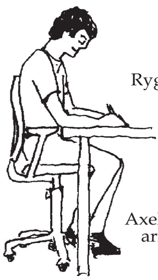
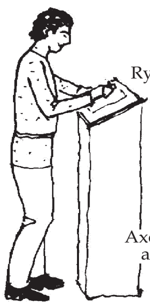
Table 8.4: A succession of legal provisions from the Swedish Work Environment Authority that regulate the workplace in order to prevent work-related MSDs and other risks to worker well-being and safety.

AFS 1998:1	*Ergonomics for the Prevention of Musculoskeletal Disorders, provisions* (in English) (Swedish Work Environment Authority, 1998)
AFS 2001:1	*Systematic Work Environment Management (AFS 2001:1Eng), provisions* (in English) https://www.av.se/globalassets/filer/publikationer/foreskrifter/engelska/systematic-work-environment-management-provisions-afs2001-1.pdf
AFS 2009:2	*Workplace Design (AFS 2009:2Eng), provisions* (in English) https://www.av.se/globalassets/filer/publikationer/foreskrifter/engelska/workplace-design-provisions-afs2009-2.pdf
AFS 2012:2	*Physical ergonomics and work environment* (most recent, in Swedish) – ***replaces AFS 1998:1*** https://www.av.se/globalassets/filer/publikationer/foreskrifter/belastningsergonomi-foreskrifter-afs2012-2.pdf
AFS 2015:4	*Organisational and social work environment (AFS 2015:4Eng), provisions* (in English) https://www.av.se/globalassets/filer/publikationer/foreskrifter/engelska/organisational-and-social-work-environment-afs2015-4.pdf

work environment improvements. Each provision is marked by the year of publication and serial number, e.g. AFS 2012:2. Arbetsmiljöverket also assigns specific responsibilities to employers and employees to jointly carry the responsibility for workplace safety and health, although most of the specifics of workplace design befall the responsibility of the employer.

As described in Berlin et al (2009 pp. 941–942), "It is stated explicitly in the [AFS 1998:1] provision that an employer is responsible for continually maintaining a healthy workplace for the employees. The provision contains guidelines for assessment of work posture, duration of work cycles, lifting requirements and relevant conditions which increase or decrease the harmfulness of the work posture (e.g. duration of postures, repetitiveness, spatial dimensions of the workplace, weight of handled objects and possibilities of gripping them, freedom to autonomously decide when to take breaks, etc.) The values for boundary conditions in AFS-98 are stated to be valid for work shifts of four to eight hours in duration".

The Swedish legal provision AFS 2012:2 (Swedish Work Environment Authority, 2012) was released as an update of the previously used provision AFS 1998:1 (Swedish Work Environment Authority, 1998), and therefore the guidelines of both documents have more or less the same coverage. The guideline provides a variety of evaluation criteria for assessing the physical ergonomics of workplaces. The general principle is that most criteria are evaluated on a scale of green-yellow-red, with green being acceptable and red being unacceptable, and yellow requiring further investigation. The provision is intentionally vague with some room for interpretation, in order to be relevant for a variety of workplace types. This means that ergonomics expertise is recommended in order to use the guideline correctly (preferred analysts are physiotherapists or ergonomists), so most places that adhere to the AFS 2012:2 have in-house ergonomics specialists (such as an Occupational Health Service) to make the assessments.

Arbetsställning	Rött	Gult	Grönt
Sittande	Något av nedanstående förekommer **under en väsentlig del** av arbetsskiftet.	Något av nedanstående förekommer **periodvis** under arbetsskiftet.	Nedanstående gäller för **en väsentlig del** av arbetsskiftet.
Nacke 	– böjd – vriden – samtidigt böjd och vriden – kraftigt inskränkt rörelsefrihet	– böjd – vriden – samtidigt böjd och vriden – kraftigt inskränkt rörelsefrihet	– i mittställning – möjlighet till fria rörelser
Rygg	– böjd – vriden – samtidigt böjd och vriden – kraftigt inskränkt rörelsefrihet – stöd för ryggen saknas	– böjd – vriden – samtidigt böjd och vriden – kraftigt inskränkt rörelsefrihet	– möjligheter till fria rörelser – väl utformat ryggstöd – möjlighet att växla till stående
Axel/arm	– handen i eller över skulderhöjd – handen utanför underarmsavstånd utan avlastning	– handen i eller över skulderhöjd – handen utanför underarmsavstånd utan avlastning	– arbetshöjd och räckområde anpassade till arbetsuppgift och individ – god armavlastning
Ben	– otillräcklig plats för benen – inget stöd för fötterna – kraftigt inskränkt rörelsefrihet – ben- eller fotmanövrerat pedalarbete*)	– otillräcklig plats för benen – inget stöd för fötterna – kraftigt inskränkt rörelsefrihet – ben- eller fotmanövrerat pedalarbete*)	– fritt benutrymme – bra fotstöd – sällan ben- eller fotmanövrerat pedalarbete*) – möjlighet att växla till stående
Stående/gående			
Nacke 	– böjd – vriden – samtidigt böjd och vriden – kraftigt inskränkt rörelsefrihet	– böjd – vriden – samtidigt böjd och vriden – kraftigt inskränkt rörelsefrihet	– upprätt ställning – möjlighet till fria rörelser
Rygg	– böjd – vriden – samtidigt böjd och vriden – kraftigt inskränkt rörelsefrihet – ostabilt eller lutande underlag	– böjd – vriden – samtidigt böjd och vriden – kraftigt inskränkt rörelsefrihet – ostabilt eller lutande underlag	– upprätt ställning – möjlighet till fria rörelser – möjlighet att växla till sittande
Axel/arm	– handen i eller över skulderhöjd – handen i eller under knähöjd – handen utanför ¾ armavstånd från kroppen	– handen i eller över skulderhöjd – handen i eller under knähöjd – handen utanför ¾ armavstånd från kroppen	– arbetshöjd och räckområde anpassande till arbetsuppgift och individ
Ben	– otillräcklig plats för ben och fötter – ostabilt underlag – lutande underlag – ben- eller fotmanövrerat pedalarbete*)	– otillräcklig plats för ben och fötter – ostabilt underlag – lutande underlag – ben- eller fotmanövrerat pedalarbete*)	– fri rörelsemöjlighet på stabilt, halksäkert, jämnt och vågrätt underlag – inget ben- och sällan fotmanövrerat pedalarbete*) – möjlighet att växla till sittande

*) Benmanövrerat pedalarbete = bromsen eller kopplingen på en bil
Fotmanövrerat pedalarbete = gaspedalen på en bil

Figure 8.4: Example of red-yellow-green guidelines from the AFS 2012:2 provision (Swedish Work Environment Authority, 2012 p. 37), showing work conditions at different risk levels for sitting and standing work.

SELECTING A SUITABLE EVALUATION METHOD

In order to determine which method is best to analyse the task in question, the following questions should be answered to help you choose which method is most suitable.

What is the main characteristic of the task?

- Does the task involve hand-arm intensive work? Does it involve lifting, lowering, pushing, pulling or carrying? Is it a heavy, intensive task, or a light but constant load?
- Some tasks involve large forces, times or postures. Is one of these aspects dominant over the others?
  - Is the objective to describe, brainstorm or rate the work task?
  - Do we want a quick "screening" for a prioritization?

Nature of the problem

- Where do we predict that problems of incorrect working use will arise?
- Is the problem caused by motion or static postures?
- Is the task particularly intensive for a certain part of the body?

What can we measure in this task?

- Measure joint angles, time for the task, the forces or weights involved, and the distances travelled (if applicable). Are any of these measurements remarkable?
- If you find an extreme measurement, this might help you select an analysis method.

How does the task relate to the measurements of the person doing the work?

- Observe the person performing the task. Are there any specific operations of the task that increase the load, posture or discomfort because of the worker's body dimensions?

Study questions

Warm-up:

Q8.1) What do the acronyms RULA and REBA stand for, and which work sectors did they originate from?

Q8.2) What are the limitations of posture-based ergonomics evaluation methods?

Q8.3) When designing lifting tasks, what limitation in applicability does the NIOSH lifting equation have for a female population?

Q8.4) What are the limitations of heuristic evaluation?

Look around you:

Q8.5) Select and examine one (or more) of the workplace ergonomics standards listed in Table 8.3 or 8.4. Do they give a high level of detailed direction for how to design a workplace, or are they flexible in their criteria in order to suit many different work sectors?

Q8.6) Use one (or more) of the posture evaluation worksheets listed in Table 8.1 and try to recreate a posture that corresponds to the worst possible posture score in all categories. Is this a likely work posture for any reason? Try adjusting just one of the posture components to the lowest possible score. What is the impact on the total posture score?

Q8.7) Look through the list of ergonomics evaluation methods in Table 8.1 – can you imagine any particular work sector where the method would be suitable, based on the body segments and additional factors targeted in each method?

Connect this knowledge to an improvement project

- Established ergonomics evaluation methods can aid workplace designers in identifying and ranking ergonomic risks, so that the most hazardous risks are addressed as a first priority.
- Use the same method to evaluate risk before and after an intervention, to give a relative quantification of whether the risk level of a task has improved.

Connection to other topics in this book:

- Most ergonomics evaluation methods rely on the anatomical limits and principles described in Chapter 2 and Chapter 3.
- Many ergonomics standards set safety limits not only for physical loading, but also for environmental factors (Chapter 12) that may contribute further to loading of the body and mind.
- Some methods are especially targeted at manual materials handling (Chapter 10), which is a special loading situation with particular demands on workers.

Summary

- Many different ergonomics evaluation methods exist to simplify and standardize the assessment of physical loading in workplaces.
- If an evaluation is based on "rules of thumb" for what is considered good ergonomics, it is called a *heuristic evaluation*. Such an evaluation demands substantial ergonomics expertise (e.g. being a certified ergonomist or physiotherapist) on the part of the analyst to correctly and comprehensively identify risks.

- Some more formalized "checklist" and "worksheet" methods exist, many of which rely on workplace observation (either on-site or analysis of photos and video).
- Some ergonomics evaluation methods are posture-focused (e.g. OWAS, RULA, REBA, HARM), others target force exertion and biomechanical loading (NIOSH lifting equation), while others simply set acceptability limits for particular populations (Liberty Mutual materials handling tables).
- Only a few methods include time aspects like fatigue, repetitiveness and exposure time. (e.g. the Job Strain Index)
- Certain methods cover a wide range of aspects to also reflect the impact of the work environment, equipment, protective gear, etc. on the ability to perform work (e.g. KIM, RAMP, EAWS).
- Evaluation and analysis using the same method should be conducted both before and after workplace redesigns, to document and monitor progress and to enable follow-up of whether an intervention has eliminated the risk.

Notes

[1] An important condition to be aware of is that while the NIOSH load constant of 23 kg is considered safe (under ideal lifting conditions) for 99% of a male population, it is considered safe for only 75% of a female population. The root cause of this condition is that the acceptability criteria for manual lifting were originally developed to cover 90% of a working population composed equally of men and women (Waters et al., 1994 p. 759).

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