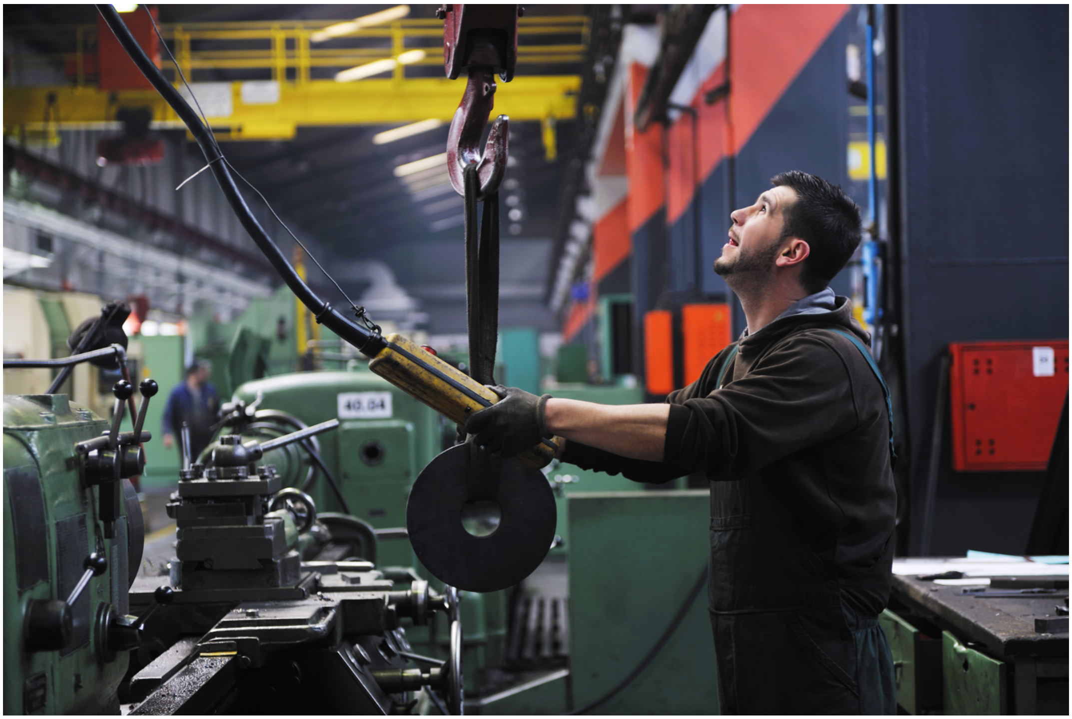
CHAPTER 3

# Physical Loading

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## THIS CHAPTER PROVIDES:

- A description of the three components of loading.
- Descriptions of the body's response to loading.
- A brief overview of simple biomechanics.

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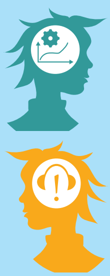
## WHY DO I NEED TO KNOW THIS AS AN ENGINEER?

This chapter will help you understand how much physical loading is acceptable in the workplaces you design. Based on the knowledge you have acquired in Chapter 2 (Basic Anatomy and Physiology), you now have an understanding of how the body's locomotive structures allow movement and the handling of loads. In this chapter, we turn that anatomical and physiological knowledge into mechanical principles of loading, allowing you to identify, analyse and evaluate the greatest risks for physical injury in the workplace.

One of the great strengths of engineering is the ability to make simplifications in order to calculate how much loading the body is under. If you have limit values available, biomechanical calculations can tell you whether a chosen task, in terms of posture, forces and time, will push the human beyond his or her limits. These simplifications are the basis for most ergonomics evaluation methods, which are explained in Chapter 8.

When you can identify unhealthy physical loading based on principles, you can reason your way into better decisions when choosing design solutions for the workplace.

## WHICH ROLES BENEFIT FROM THIS KNOWLEDGE?



For the *system performance improver* and *work environment/safety specialist* striving to identify improvement potentials in a workplace, the previous chapter's anatomical and physiological knowledge may be overwhelming to keep in mind and difficult to separate into analytical components in order to look for risks in a structured way – therefore, this chapter provides an intermediate step along the way to the ergonomics evaluation methods by showing how the body's reactions to loading can be simplified into some main components that can be systematically observed and later targeted in improvements.

## 3.1. The components of physical loading

As you learned in Chapter 2, Basic Anatomy and Physiology, the body's tissues work together to withstand many different types of biomechanical loading. Exceeding the body's physical ability to handle these loads results in pain and physical injury, which can be either sudden or chronic. But if we regard the problem from an engineering perspective, we need concepts and methods to identify what exactly makes physical loading a risk.

To make this possible, we adopt the view that:

$$\textbf{\textit{Physical Loading}} = \textbf{\textit{posture}} \times \textbf{\textit{forces}} \times \textbf{\textit{time}}$$

Body posture demands that the body's muscles actively work to maintain a position, which is a form of *internal loading.* The posture aspect includes how internal forces are distributed across the different parts of the body (for example, lifting something off the ground with a straightened back engages mostly the leg muscles which are large and strong, while lifting the same object with a bent back loads the upper torso which has smaller, weaker muscles).

*External loading* occurs as a result of handling weights, e.g. by pushing, pulling, lifting, pressing or dragging something. Generally, when force is counted as a component of loading, we are mainly referring to external loading. In some biomechanical analyses, the weights of the human's own body parts are sometimes also considered a load, especially if gravity influences the chosen posture.

Finally, time factors describe how long, how often or how frequently the body's structures are loaded. Since you now know that the muscles and tissues can work for a limited time until they are fatigued and need to rest, the level of risk depends on whether the exposure is suitable for strength- or endurance-type body structures. The time component most frequently focuses on repetitiveness, which is considered a major health risk because the body's structures are not allowed enough recovery between loadings.

## 3.2. Posture

Posture denotes how the body is aligned and positioned, especially in states of activity. A posture can occur as a result of consciously choosing how to position the body, or less voluntarily as a result of adapting to available space, tool sizes, visual demands, pain, etc. Posture may be influenced by the contextual factors in Table 3.1.

### *Good and bad posture*

There is a conception of "good" and "bad" posture, stemming from societal norms about keeping the body upright, symmetrical and well aligned. From a work design perspective, good posture is more than keeping your head upright and your back straight – it also includes strong hand postures, equal weight balance between the legs, and deliberately handling external loads close to the centre of the body. As a useful, operative definition for engineering work, we can define good and bad posture as follows:

> **Good posture** is a position where the functional structures of the body are in the best possible position to exert high force or high-precision movements, as required by the work task (Figure 3.1). Indications of good posture are balance, symmetrical distribution of forces on the body parts, and skeletal (rather than muscular) loading.
> **Bad posture** is a position where body is in a weak position to perform physically demanding work. Bad posture puts the body tissues under extra, unnecessary physical load that does not contribute to the task at hand. Indicators of bad posture include positions at the outer range or movement (hyperflexion or hyperextension), asymmetry, imbalance between the legs, slumping, and forced muscular loading rather than skeletal loading.

As stated in Chapter 2, different parts of the body are specialized for different types of movement and loading. For example, the back and legs are excellent at withstanding heavy loads for a long time

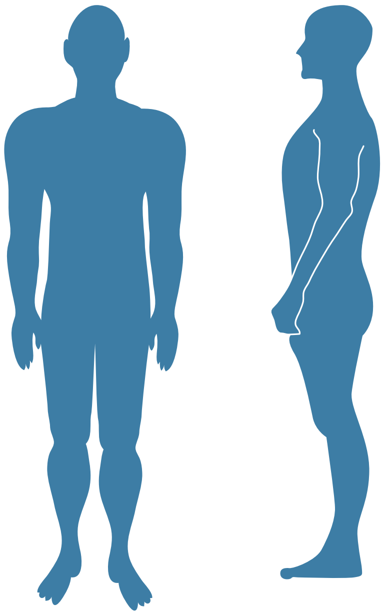
**Table 3.1:** Factors that may influence body posture.

| | |
|---|---|
| **SPACE** | Humans are good at adapting body posture to existing preconditions in order to fulfil a task. This may often involve twisting or turning the body in order to reach, fit into an inconvenient space or avoid touching the surface of materials (example: so as not to scratch the paint job of a car). Therefore, it is necessary to determine how much working space around the task will be enough to avoid unnecessary loading, and whether to design for a minimum amount of space or with safety margins. A related aspect is to consider whether the available space will suit all body types and sizes[1]. |
| **VISION** | An important prerequisite for performing a task is often being able to see what we are doing. If the line of vision is blocked or inconvenient, a human will often move the head, neck or upper torso to improve the line of sight, often bending or twisting. Therefore, visual demands can certainly influence posture. Also, insufficient lighting may have a similar effect even when the line of sight is acceptable, since it may still lead to bending closer to see controls, screen interfaces or instructions. It is a wise safeguard to have a well-lit working environment, particularly to ensure the ability to see[2] written information for workers of all ages. |
| **STRESS** | A high pace of work or high mental load (demanding tasks or working under pressure to perform) can contribute to feelings of stress. Heightened stress levels often increase muscular tension in the body, leading to a persistent internal loading situation that is static and can lead to fatigue. In some cases, tension from stress leads to cramping up and discomfort or pain. Stress can result from the psychosocial environment, demands of the job, the task speed or perceived mismatch between the task and the human's abilities. |
| **PROTECTIVE CLOTHING** | Many environments and tasks demand that the workforce should wear protective gear and clothing – sometimes to protect the human from extreme temperatures, glare, hazardous materials, wetness or dirt (e.g. gloves, glasses, jackets, helmets or visors), and sometimes to protect sensitive products or the environment from humans (e.g. hygiene masks and gloves). From a loading perspective, it is important to consider the additional postural load that these safety measures can bring about. For example, a helmet or visor may be heavy or warm, resulting in extra muscular effort and heat. Another example is that wearing gloves can often reduce surface friction and the sense of touch, leading to compensation with higher grip forces or clumsy use of hand tools.<br>Finally, it is worthwhile to consider that protective clothing can impede both movement and vision. |

if loaded in their axial direction, while the hands are highly flexible and responsive instruments of precision work rather than strength. Granted, with training some people are able to increase their force exertion in the hands or the precision of their back and leg movements, but it is generally reasonable to design tasks and workplaces so that they cater to what the body segments are naturally best at.

### *Causes and consequences of bad posture*

Bad posture is often accompanied by initial warning signals in the form of tension, discomfort or pain. It often results from unawareness, ignoring signs of pain or discomfort, or underestimating the impact of low-level long-term loading. There is a conception that there are several ergonomics pitfalls



***Good Body Posture***

- Feet firmly planted on the ground
- Knees directly above the middle of the ankle joints
- Hips directly above the knees
- Shoulders squarely above the hips
- Head and neck held in a way that aligns the ear directly over the shoulders

**Figure 3.1:** Characteristics of good body posture (for the purpose of being ready for additional loading)
Illustration by C. Berlin.

or typical scenarios that people often brush off as “not so bad” or just a minor inconvenience, but which may lead to risk for injury. These include:

- stretching to reach
- repeated heavy lifting
- lifting large, bulky, awkwardly shaped objects alone
- high pinch forces
- handling sharp, hot or cold objects
- working with hands above shoulders
- long periods of work holding the same body posture

As mentioned earlier, additional demands (such as seeing, avoiding touching surfaces, psychosocial issues, or compensating for protective gear with posture or force) may be part of these ergonomics pitfalls. Observable work behaviours include bending, pushing, pulling, lifting, hand twisting, unbalanced standing or sitting, and repetitive actions.

Some postures themselves can cause static loading on the body, meaning that forces or torques are applied for so long on the engaged body parts that they are not given sufficient rest. This can lead to fatigue, decreased force/precision performance, and compensation recruitment of extra muscle fibres. In many cases, static loading leads to constant tension in the muscles which can lead to tiredness, discomfort and cramping or even headaches. Such static postures and loading situations include:

- bending the back forwards or sideways
- holding loads in the hands

- stretching the arms out to the sides or raising them above the shoulders
- putting weight on one leg, while the other works (e.g. a pedal)
- standing in one place for long periods
- sitting in one place for long periods (e.g. computer work or driving a car)
- pushing and pulling very heavy objects
- tilting the head forwards or backwards at the extreme end of motion to see
- raising the shoulders

### *Measuring posture*

How, then, can we determine if a posture in itself is harmful? A good rule of thumb is that if a posture is held near the outer range of motion, it is probably not a good position for taking on external forces. For many ergonomics evaluation methods, posture is defined in terms of joint angles between body segments. A "neutral" posture is considered the least amount of loading, and resembles a relaxed, standing, symmetrical body position with the arms hanging along the sides of the body (Figure 3.2). Deviating from this relaxed, standing posture is considered an increase in risk for harmful loading.

For situations where work postures are being observed or assessed manually, rough estimates (based on the expertise of a trained eye) of the joint angles are often sufficient, but for analyses that require more precise values for joint angles, the following measurement methods exist:

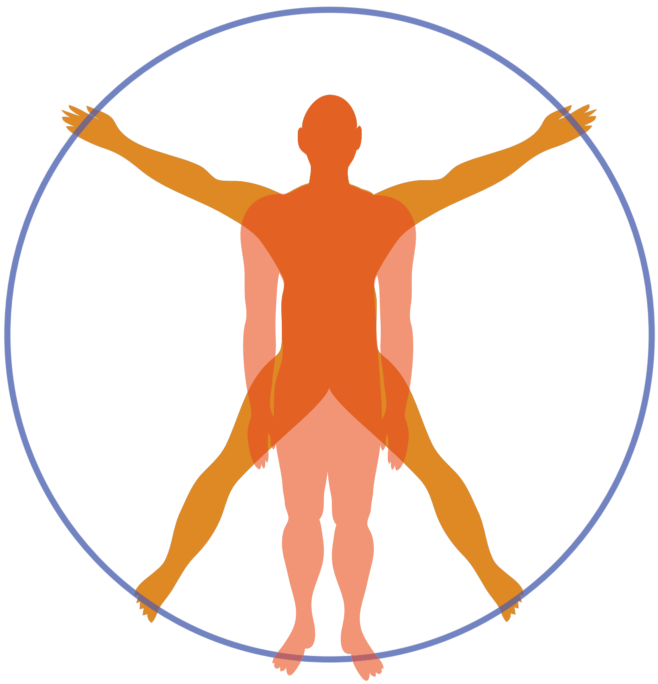
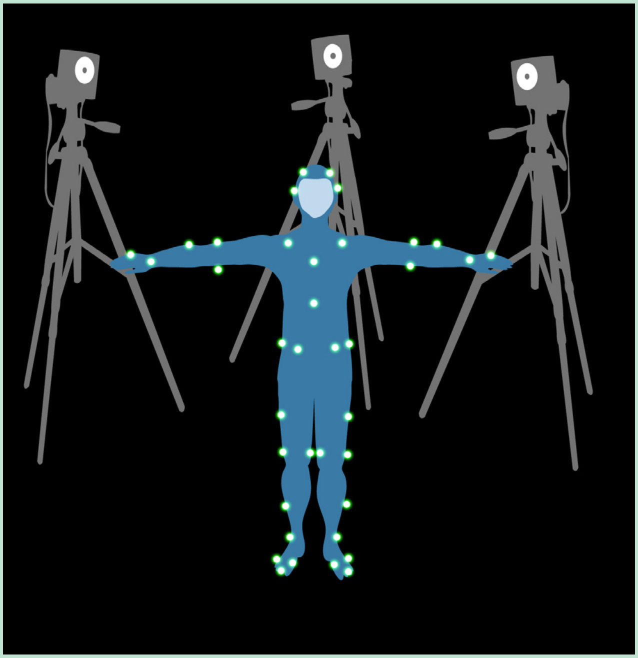


**Figure 3.2:** The basic "neutral" posture (red), typically considered as the lowest risk for harmful loading, and a near-maximal deviation of limbs (orange) from that neutral position, generating biomechanical torque on most joints. Bending and twisting also lead to deviation from the "ideal" starting posture.

Illustration by C. Berlin.

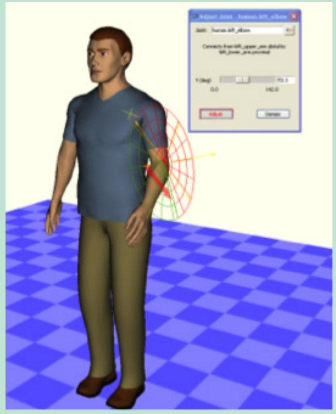
**Goniometers**[a] are graded tools used to measure angles between body segments.

**Inclinometers** are electronic devices that can be mounted to body segments to continually log and measure the "leaning" or inline of body parts in different positions.



**Motion capture** has been used primarily by the film and games industries to record the motions of a real human being performing movements. Early motion-capture technologies often involved attaching electrodes with wires to different body segments. Today, this is usually done by one of two ways: 1) *visual motion capture*, where the person is strapped with reflective visual markers, and recording of the person's movements is from all angles, using several different cameras simultaneously, and 2) *wireless motion capture*, where digitally connected sensors with inclinometers are oriented to a 3D coordinate system in a computer and wirelessly transmit human movement as the recording progresses. The result in both cases is a file that registers how the markers move relative to each other in a 3D space. This recording can be imported into ergonomics evaluation software, and joint angles and various risk levels can be easily deduced from…

…**Manikins**[b], which are 3D representations of humans in a 3D CAD environment that can be posed and made to move. Since manikins are frequently used to evaluate posture and ergonomics, exact joint angles are generally easy to obtain from the software that the manikin is used in.



[a] Images by C. Adams (Goniometers and Inclinometers) and C. Berlin (Motion Capture).



## 3.3. Force

Force in itself is only a risk if it exceeds the limit loading values of the body's structures. Some of these limits are determined by materials science values for body tissues, but a certain degree of ability to handle large forces actively can be influenced by training, health status, nutrition levels and genetic preconditions.

In static mechanics, a force is traditionally thought of as a vector arrow with a certain magnitude and direction, acting on a point. But to study the impact of real-life loading forces, we need a more nuanced vocabulary to do justice to forces. Table 3.2 shows some different terms by which we can characterize force.

**Table 3.2:** Terminology concerning forces.

| | |
|---|---|
| **MASS** | The inert weight of objects that are not in motion, expressed in kg or lb. |
| **DYNAMIC FORCES** | Forces that have variation in magnitude and direction, engaging different muscle groups and leading to aerobic (oxygen-based) processes in the muscles. |
| **STATIC FORCES** | Forces that affect a limited muscle group for a sustained period of time, allowing little or no rest and recovery. This leads to discomfort, fatigue and anaerobic processes (production of painful lactic acid) in the muscles. |
| **REPETITIVE FORCES** | A special case of static loading, these are forces that are short in duration, but occur so frequently that the muscles are not able to relax in between loadings, meaning that their overall load is equivalent to a static force. |
| **EXTERNAL FORCES** | External forces often occur as a result of handling objects by pushing, pulling, lifting, lowering and carrying. |
| **INTERNAL FORCES** | Internal forces arise when the body's muscles strive to maintain a posture, either as a reaction to external loads or because of higher internal pressure at the extreme ends of our range of motion. |


**Figure 3.3:** Force gauge for measuring push and pull force. The readout is often given in *N*.
Photograph by C. Adams. All rights reserved.

### *Measuring force*

As with posture, rough estimates can go a long way, but it is often necessary to get a value on the force being applied to judge its risk impact. A very rough yet effective method is to use weigh scales (such as bathroom scales or luggage scales with a hook, Figure 3.3) to measure push and pull forces expressed in kilograms or pounds. This can then be roughly approximated into force expressed in Newtons by multiplying the gravitational factor 9,.82 $m/s^2$. For more exact force measurements, force gauges for measuring pushing or pulling motions can be used (see Figure 3.3).

## 3.4. Time

Time factors can significantly influence the occurrence of work-related MSDs and make a seemingly small and harmless load into a risk for long-term injury due to wearing out the body. Primarily, it is important that loading from tasks must be suitable for the body tissues that are engaged and that they are allowed sufficient rest and recovery between exposures. Exposure can be defined as the time duration that the body's structures are actively engaged in order to perform a task, usually in order to sustain a force or torque.

**Table 3.3:** Terminology of time exposures.

| | |
|---|---|
| **REPETITIVENESS** | Repetitiveness, also known as "monotonous work", is thought of as the potentially most harmful time exposure factor. Generally, the magnitude of force is not the problem with repeated loading; the lack of recovery is. Since repeated motions affecting the same muscle groups lead to little or no time for rest, this type of exposure is considered equivalent to static loading.<br>Definitions in scientific literature vary regarding limit values for repetitiveness, but many definitions count the number of "same" actions that occur every 30 seconds (Zandin, 2001).<br>Repetitiveness can be either measured as the speed at which the operator carries out the tasks, or it can be measured in terms of the number of movements or posture changes per shift. |
| **FREQUENCY** | Frequency designates the number of occurrences per time unit that a muscularly similar action occurs. Repetitiveness is often expressed in terms of frequency. |
| **CYCLE TIME** | The inverse of frequency is the cycle time, i.e. time duration per completed motion or task. |
| **ENDURANCE TIME** | The period of time before fatigue sets in; until that time, the body tissues can tolerate constant or repeated loading and still function to a satisfactory level of speed, precision and/or strength. |
| **FATIGUE** | The state where musculo-skeletal structures are loaded to the extent that they can no longer exert sufficient force, speed, precision or motion range anymore. At this stage, rest must begin to achieve recovery and rebuild safety margins against physical injury. |
| **RECOVERY** | The state where musculo-skeletal structures are free of discomfort, tiredness and pain related to exposure, and are once again ready to take on loading. |
| **RESUMPTION TIME** | The time it takes between reaching the stage of fatigue and when the worker feels ready to resume the activity or task. |
| **CUMULATIVE LOADING** | Cumulative loading is the notion that load exposures add up over time, and that some injury risks are difficult to identify unless the loading is considered over different time perspectives. This is especially true if there is routinely insufficient rest or recovery. For example, load risks may not be evident when studying cycle times of ~30 seconds, but may emerge if the loading is considered over an hour, over a shift, over a day, a month... all the way up to an entire working life. For some manual labour professions, certain types of loading may have a significant physical impact over the course of a working life. |
| **VARIATION** | The main remedy against harmful time exposures is to introduce variation – this means doing a variety of different tasks after each other to avoid repetitive motions. It is believed that even if muscular activity remains high, spreading out the loading on different body structures gives the different muscle groups a chance for relative rest and recovery. |

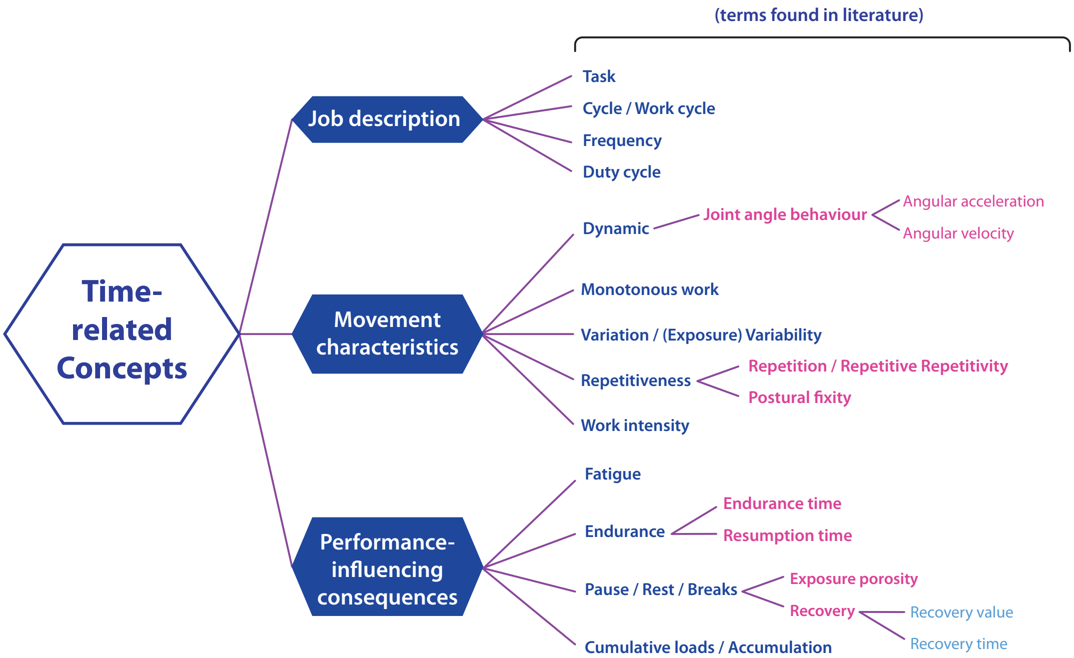



**Figure 3.4:** A hierarchy of time-related factors that can be used to describe production assembly work. (Adapted from Berlin & Kajaks, 2010).

llustration by C. Berlin, based on Berlin & Kajaks (2010).

## 3.5. Interaction of posture, forces and time

It is important to remember that the interaction between posture, force and time may sometimes increase or decrease the total risk (increased probability and severity of injuries) considerably. It is for instance not necessarily true that lifting heavy weights is always a risk; this is acceptable as long as it is done infrequently (to ensure recovery) and with good posture. In contrast, small, persistent loadings over a long time period can be much more harmful than they seem, because weak structures that are constantly nearing fatigue can "drag along" neighbouring body structures into compensating with muscular tension.

Sometimes, the nature of the task can also influence whether loading is harmful or not. Often it is a question of whether the three components are of a suitable magnitude. You learned earlier that high-precision work with the hands is not good to combine with maximum force. It then follows that different hand postures or grips are ideal for high-precision or high-power work respectively. However, some postures alone will raise the risk greatly – working with highly flexed or extended wrists is both harmful and ineffective, since most extreme-range postures lead to nerve and tendon entrapment and provide a weak position for transferring force.

To describe the risk levels of these factors combined, the *cube model*[3] (Sperling et al., 1993) gives each of the loading components three criteria levels of severity (where 1 = low risk and 3 = high risk) showing which combinations may result in harmful loading or injuries. Figure 3.5 shows that a high level on just one out of three components may be acceptable as long as the value is lower than 6,

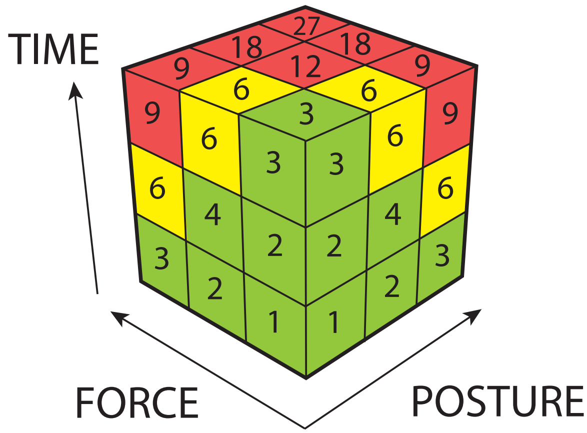



**Figure 3.5:** The cube model, showing how different combinations of posture, forces and time result in different risk levels. (Adapted from Sperling et al., 1993).

Illustration by C. Berlin, based on Sperling et al. (1993).

(green zone), while a combined level that is higher lands in the yellow (6 and above, but under 9) or red zones (9 and above), indicating that the load must be reduced (red) or at least investigated (yellow).

### 3.6. Other factors influencing physical loading

Some additional non-anatomical factors in a work environment may affect physical loading in a way that engages all three loading components or combinations of two of them.

**Table 3.4:** Factors that may have influence on body posture.

| | |
|---|---|
| **VIBRATIONS** | Vibrations are a special form of loading; different body tissues have different resonance frequencies and therefore have different sensitivity levels to vibration forces. The body spends the entire times it is exposed to vibration compensating muscularly for small external forces that act in opposite directions on the body. This compensation tension can lead to sustained strain, over time resulting in cumulative trauma disorders. |
| **ENVIRONMENTAL FACTORS** | Cold, heat and humidity can affect contact comfort, grip friction, forces required, avoidance of burning or chill, etc. |
| **NON-RIGID MATERIALS HANDLING** | Rubber, fabric, cables, etc. are often large, floppy, sometimes elastic and difficult to manage in a consistent standard way. Extra force exertion may be necessary due to friction, dragging material on the floor, elastic behaviours and entanglement. It is also difficult to measure the forces required, both during carrying and during assembly. |
| **HIGH-PRECISION WORK** | High-precision work increases demands on performance and requires extra suitable working conditions and postures in order to be executed efficiently and with high quality. |

### THE "CINDERELLA HYPOTHESIS"

Hägg (1991) proposed a theory of cumulative loading known as the "Cinderella Hypothesis", named after the fairy tale character that was always "first to rise and last to go to bed". This theory aims to explain why there is a risk for injury even when humans perform tasks with low forces over prolonged time duration.

The basic idea is that when a motion occurs and the muscle contracts, certain low-threshold (weak) motor units are recruited first (with other stronger ones successively joining in as the motion continues) and are deactivated last. This means that when motions are repetitive, some muscle fibres run a greater risk of injury, because even though the motion stops briefly, the first recruited fibres remain constantly activated at low loads, meaning that there is no recovery. This leads to fatigue, pain and possibly cumulative strain injuries. This theory helps to explain low-load musculo-skeletal problems in the neck, shoulders and wrists, such as mouse arm and writing cramps.

## 3.7. Biomechanics

This book only gives a very brief overview of biomechanics, for the purpose of introducing you to the basic assumptions and simplifications behind many ergonomics evaluation methods. It is not intended to be extensive, so it will only bring up some very simple examples. To read more extensively on the subject, please consult a dedicated textbook of biomechanics, such as Knudson (2007).

## 3.8. Applying mechanics to the human body

The human body is made up of many different tissues (bone, muscles, nerves, ligaments, etc.) that all have different mechanical properties, for example limit values for loading and strain. Furthermore, they can move in a three-dimensional range of motion during loading. However, it is possible to simplify calculations of how much the body can be loaded using simple laws of mechanics, and by considering motions in a simplified way: by studying the forces and torques acting on the body at different "before" and "after" positions in a two-dimensional plane. The biomechanical calculation is often made with loading on a specific body part as reference, and generally, there is a limit value for how much force or torque that body part can safely withstand. However, since exact biomechanical calculations are extremely complicated, a simplified equation must be built on many assumptions. To be able to trust the simplification of the physics acting on the body, the limit value for how much a body part can be loaded should be calculated conservatively – in other words, the safety of the body is ensured by considering its weakest link.

Some basic assumptions (or simplifications) made in biomechanical calculations are that:

- Skeletal bones are considered as rigid bodies (no plasticity).
- Joint motions are considered in one direction.

- There is no friction in the joints.
- Torque is considered to affect only one muscle or muscle group in one direction.
- There are no antagonistic muscle forces.
- The mass of the body segment is calculated as a percentage of total body weight.
- Body weight and measures for centre of gravity are taken from anthropometric literature data.

### *Stress, strain and trauma*

In a biomechanical sense, stress is defined as potentially harmful loading. Stress is usually the result of forces or torques acting on the body structures, up to the point of strain, meaning that the structures experience deformation as a result of the loading. This in turn goes to the point of trauma, which means that the structures fail or break. Every tissue in the human body has its limit value of stress that it can withstand before failure. As long as loading is beneath that value, the structure is safe, but above it, risk for injury is present.

### Study questions

*Warm-up:*

**Q3.1)** What is the difference between internal and external loading?

**Q3.2)** Name some causes of bad posture that may arise from the work task and work environment.

**Q3.3)** What is the difference between dynamic and static loading?

*Look around you:*

**Q3.4)** Find some videos online (for example on YouTube.com) showing physical assembly work tasks; can you use the posture/forces/time triad to identify risks for unhealthy physical loading?

**Q3.5)** Reflect on your own working life as a student, engineer or the like. What are the typical postures, forces and time frequencies of exposure that occur in your daily life? Are you at risk for unhealthy loading?

### Connect this knowledge to an improvement project

- When observing physical work, look for recurring posture-, force- and time-related risk occurrences.
- Try to identify the root cause – in the task or environment – that may cause or contribute to the previously mentioned risk exposures.

- Ask operators why certain behaviours are adopted. If there is a known reason, this will perpetuate the risky behaviour and should be addressed. What function does the answer to that "why" fill?

### Connection to other topics in this book:

- Some ergonomics evaluation methods (Chapter 8) specifically target one or more of the risk factors of posture, forces and/or time. When choosing a method, consider that:
  - Many methods are purely posture-based (Chapter 8), meaning that they may exaggerate the severity of the posture if it is not frequently occurring.
  - Time-related evaluation methods are not commonly covered; at least not with observation-based methods that you can perform on-site. Usually some assumptions are needed.
  - Force-related evaluation exists and is well backed up scientifically, but many of these guideline rules are limited to a specific population (for example, by being valid mostly for men), so it is worthwhile to be aware of how anthropometry (Chapter 4) dictates how relevant these methods are.

### Summary

- Physical loading is a combination of posture, force and time.
- Posture dictates how the body is aligned and positioned and is influenced by space, vision, stress and protective clothing.
- To maintain a certain posture the muscles must actively work; this is a form of internal loading.
- A good functional working posture is one in which the body is balanced, forces are symmetrically distributed over the body and external loads are held close to the body while both feet are firmly planted on the floor.
- Bad demanding postures, where there is an imbalance between the legs, extensive muscular loading and movements at the outer range should be avoided where possible.
- A neutral posture where the body is relaxed and symmetrical with the arms close to the body is considered to involve the least amount of loading.
- Static loading when forces and torques are applied for prolonged periods of time without sufficient rest should be minimized.
- Excessive static loading can lead to fatigue, decreased performance levels, constant tension in the muscles and discomfort.
- Forces are only an injury risk when they exceed the loading value of the body's structures.
- Static forces affect a limited muscle group for a sustained period of time with little or no rest and recovery.
- Dynamic forces have variation in magnitude and direction, engaging different muscle groups.

- Forces can be both internal and external.
- Time factors describe how long, how often or how frequently the body's structures are loaded.
- Repetitiveness is one of the most harmful time factors, when repeated motions affect the same muscle groups with no time for rest.
- Fatigue is the state at which musculo-skeletal structures are loaded so much that they can no longer exert sufficient force, speed or precision.
- Rest is key to enable the body to recover from fatigue so it can function normally again.
- Variation of body postures and applied loads coupled with sufficient recovery time is very important during work.
- Applying principles of mechanics to the human body is known as biomechanics and can be used to calculate what loads the body can withstand.

## Notes

[1] We explain how to consider different body sizes in Chapter 4: Anthropometry.
[2] We explain how to consider vision and lighting in Chapter 12: Environmental Factors.
[3] Although the Cube Model was originally developed to evaluate hand/wrist loading when using hand-held tools, the logic of interaction between these loading risk components is applicable for the entire body.

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