Guidelines for the occupational health assessment of long working hours

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Preamble:

The Österreichische Gesellschaft für Arbeitsmedizin (Austrian Society for Occupational Medicine – ÖGA) is preparing a continuation and update of the guideline "Grundlagen zur arbeitsmedizinischen Beurteilung von Arbeitszeitregelungen" *(Basics for the occupational health assessment of working time regulations)*, which was published in 2007 following the revision of the Working Hours Act (AZG). The background to this were the provisions on the determination of occupational health and safety when a 12-hour day was introduced, especially in situations where there was no employee representation. Following the new amendments to the AZG in September 2018, this provision has been dropped: the introduction of a 12h day only requires the consent of the employees concerned (individual agreement, without participation of employee representatives).

Since these are changes involve the work organisation, § 4 ASchG (*Occupational Health and Safety Act*) requires a re-evaluation with regard to potential hazards and, if necessary, the implementation of measures as well as documentation in the safety and health protection documents. A further obligation exists in the ASchG for employers to inform and instruct of possible dangers and protection possibilities.

The aim of the new version of the guideline was therefore to prepare the current literature on possible health risks of long working hours, to provide support in the evaluation and evaluation of concrete working conditions in connection with long working hours and to recommend measures, in particular also for conditions that could occur with chronically ill people. The target group for the guide is primarily preventive specialists, but also employers, managers, employee representatives, safety representatives and employees who are responsible according to the ASchG.

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C O N T E N T S

1. Introduction:

The current world of work is characterised above all by two developments:

- Labour is saved wherever possible. This means that the same or increasing productivity is shared among fewer people.
- Replacement of so-called simple activities by automation. What remains are activities that cannot be automated at all or are not economical, essentially service occupations, responsible activities and management tasks as well as control and monitoring activities.

The increased pressure to perform in a working world that is becoming harder overall leads – as described and documented below – above all to an increase in stress-related health disorders, premature wastage and the resulting increase in early retirements and an increase in the accident risk. At 41.2 hours per week, full-time employees in Austria work significantly more than the EU average of 40.2 hours (Eurostat 2019). In 2018, 18% of employees regularly worked more than 40 hours a week (Statistik Austria). According to surveys (SORA, Deloitte; 2019), around 30 percent of companies are already making use of the legal option of extending their working hours or working weeks within the framework of flexitime agreements.

In addition, the pension reform of 2003 has led to a gradual extension of working life in Austria. Prolonged working life in a generally harder working world primarily affects the health and performance of older people in the work process and is therefore one of the occupational health challenges of our times.

1.1. Deterioration of the situation due to the "flexibilisation of working time"

A new regulation called "flexibilisation of working time" also includes a change in the definition of normal working time. For one simple reason, this in turn leads de facto to an extension of weekly working hours: Whereas in the past extra hours were paid as overtime and therefore had to be used sparingly for economic reasons, this regulation will lose importance in the future, so that it is to be expected that the actual weekly working time for the individual employee will increase. Under no circumstances can this be regarded as having no adverse effects on health. The short-term economic advantage this brings is likely to turn into a long-term disadvantage for the following reasons:

- Higher work performance increases the physical and psychological strain on the workers and in turn has a performance-reducing effect.
- The already problematic extension of working life for an even larger group of people than before will not be feasible as a result of higher work performance, which will additionally burden the costs of the social security system.
- It is to be expected that an extended standard working time will increase the risk of accidents. This applies not only to the individual accident risk, but especially to the increased external hazard in control and monitoring activities

In principle, we assume that this flexibilisation of the daily working time will not result in an extension of the annual working time or working life, i.e. phases with overtime (up to 12 hours a day, 60 hours a week) are followed by phases with correspondingly reduced working

time. The fact that longer working hours could result in stress- and work-related illnesses has not been sufficiently taken into account in legal regulations and left to employers and employees, and also to workers, without reference to loads and consequences. Social security and pension schemes cannot be satisfied with this if there is a risk of an increase in chronic diseases whose treatment costs would be borne by the general public.

1.2. Special occupational health problems during extended standard working hours

I. Numerous previous limit values, especially the maximum workplace concentrations in occupational toxicology, are defined for the eight-hour day and the forty-hour week and cannot be adapted to a longer period by simple extrapolation (see C H A P T E R 8).

II. Increased working hours cannot be recommended from an occupational health point of view for numerous workloads, in particular for activities which are already defined in accordance with the Heavy Labour Act. These are activities:

- in shift work
- which are regularly carried out in hot conditions
- which are regularly carried out in cold conditions
- under chemical or physical influences, if this has caused a reduction in earning capacity of at least 10%, in particular in the case of vibrations, exposure to inhaled pollutants which may cause an occupational disease
- in work-related care
- involving heavy physical work (>2000 Kcal for men; >1400 Kcal for women - these values are related to 8 hrs; the “List of occupations for women and men involving heavy physical work” is available under www.pensionsversicherungsanstalt.at)
- despite the presence of a reduced earning capacity of 80%
- for which a night shift labour contribution has been made.

1.3. Fundamental considerations in practice

In the context of the humane organisation of work, “working time” is a topic that should correspond to the ergonomic model, i.e. adapting work to people and not vice versa. The principles “practicability”, “tolerability or harmlessness”, “freedom from impairment”, “reasonableness”, “satisfaction” and “personality development” serve as fundamental, hierarchically structured criteria in this ergonomic model for assessing human work and designing it in a humane manner. Not least for these reasons, the organisation of working time is one of the traditional tasks of employee protection.

In cases where the intensity of the impact of loads could not be influenced by design measures (or where this seemed uneconomical), attempts have been made to keep these stress factors, and thus also the stresses, within tolerable or reasonable limits by limiting exposure times (Rutenfranz et al., 1993).

The organisation of working time thus represents something like the second dimension of a humane organisation of work (Janßen, D. & Nachreiner, F. 2004). The location, duration and reference areas will be the subject of the assessment, as will the working environment, physical and chemical influencing factors, the severity and nature of the activity, mental stress and even the social compatibility of the organisation of working time.

The assessment of a potential hazard can only relate to actual situations and activities, not to industries. It must be assumed that stress may have certain consequences. Therefore, changing factors such as gender or the ageing of the workforce must always be taken into account.

The basis of the guide refers to the current scientific expertise of occupational science, occupational hygiene, ergonomics, occupational psychology and occupational medicine and represents the state of the art in the assessment of working time.

As a basis and rough evaluation, standardised questions should be mentioned (see Table 1), such as

- What are the existing loads?
- What is the structure of the workforce (age, gender, education)?
- What accident risks are there and what are the effects of longer working hours or shifts?
- How were/are psychological, chemical and physical stresses recorded and assessed?
- Are there additional stresses on employees due to long working hours?
- How were/are rest breaks determined?
- How were/are ergonomic findings taken into account in the organisation and design of breaks?
- How did/will employees get to the company (routes to the workplace)?
- How was/will further qualification be ensured?
- How was/will the plannability of work assignments be ensured?

- How was/is the ageing-appropriate nature of the activity ensured?

Parameter	**Design option**
Content (What is being designed?)	
Duration of working time	Per day, week, month, year, period of life
Situation of working time	Time of day, day of week, season, period of life
Distribution of working time	Daily and weekly working hours begin and end at fixed and recurring times or the daily/weekly working time varies within defined bandwidths
Organisational (How will it be designed?)	
Variability of duration or position	Always the same, different or strongly fluctuating
Influence on the organisation of working time	Only the employer/manager, only the employees or both in agreement determine the working time, scope of scheduling
Predictability	Planning of working times short, medium or long term, frequency of changes, reliability of target times

Table 1: Parameters of working time organisation (Hornberger and Knauth 2000, Janßen and Nachreiner 2014)

2. Legal basics:

2.1. Hazard identification:

- **Definitions (ASchG) § 2.** (7)
  Risk prevention in the sense of this federal law means all regulations and measures intended to prevent or reduce work-related hazards. Hazards within the meaning of this federal law are understood to mean physical and psychological burdens caused by work which lead to stresses.

- **§ 4 ASchG**

(1) Employers shall be obliged to identify and assess the risks to the safety and health of workers. The principles of risk prevention according to § 7 are to be applied. Particular account shall be taken of:

1. the design and furnishing of the workplace,
2. the design and use of work equipment,
3. the use of working materials,
4. the design of the workspaces,
5. the design of working methods and processes and their compatibility,
6. the organisation of work tasks and the nature of activities, the working environment, work processes and **work organisation**; and
7. the state of training and instruction of workers.

- **SIGE documentation**
- **Information and instruction**

2.2. Working Hours Act AZG

Maximum limits: Legal situation since 1/9/2018

- Workers may be employed 12 hours per day, 60 hours per week (§ 9 para 1 AZG New).
- Employees can reject overtime of more than 10/50 hours without giving reasons and may not be disadvantaged for this reason (§ 7 para 6 AZG New).
- In addition, employees can choose ad hoc whether overtime over 10/50 hours is remunerated in cash or with time off in lieu (§ 10 para 4 AZG New)
- Over a four-month period, a worker may be employed for an average of 48 hours per week (§ 9 para 4 AZG).

3. What are the consequences of long working hours?

3.1. Stress/strain concept:

In accordance with the proven stress/strain concept, heavy workloads lead to psychological and physical stress in humans. External stresses are neutral and usually measurable. High loads lead to a high strain, from a certain level this leads to stress, in the medium term to complaints, health disturbances and finally to work-related illnesses. In order to avoid this, there are limit values for exposure, but the effects are a function of time, i.e. the "dose" itself leads to health problems.

The stresses triggered by loads can be influenced by moderating factors, so that a load tolerance occurs and no negative impairing factors occur. In principle, it must be assumed that multiple loads potentiate, and psychological and physical strains can also interactively lead to higher stress levels; examples are muscular strains, which can lead to higher stress during simultaneous mental strains (Figure 1).

Moderating factors include training, education, good work organization, but also a social climate and appreciative leadership.

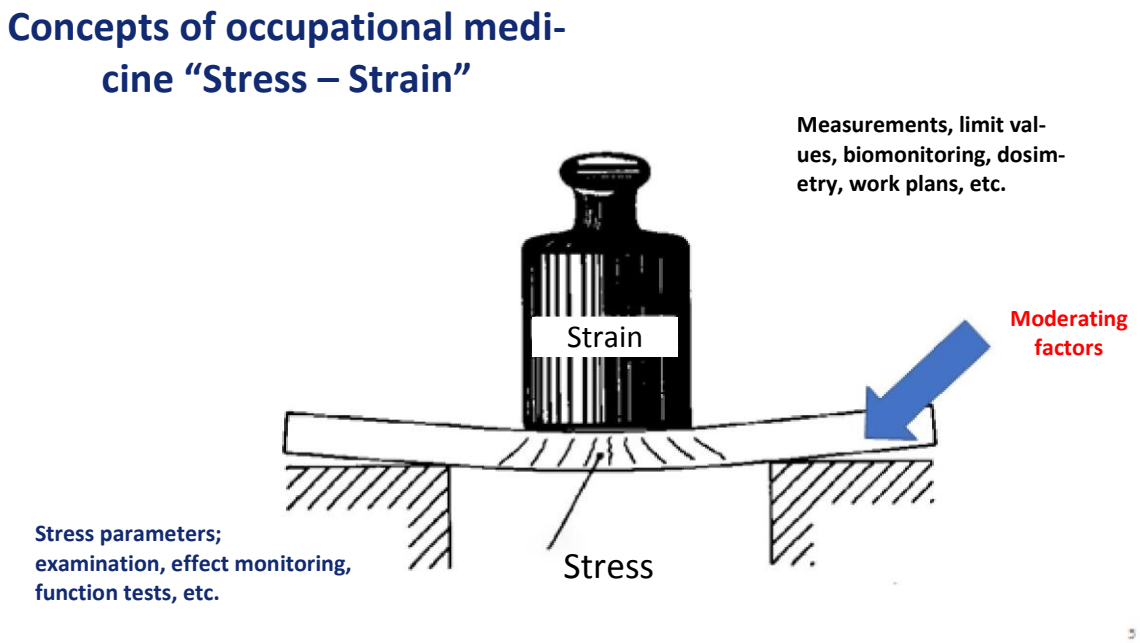


Figure 1: Stress/strain concept

Different individual conditions have different risks, which can be increased by additional influencing variables, examples can be found in Table 2:

Hazard	Low risk	High risk
		
Time	Day shift	Night shift
Start of shift		Before 6 am, after 10 pm
Breaks	Fixed, regular	Work organisation
Repetitive activity	Low	High, with higher requirements
Concentration	Low, alternating	High, longer periods
Fatigue	Can be alleviated	Work must be continued
Hazardous substances	With low risks	High risk substances
Noise	Low	High
Climate	Low heat exposure	Exposure to heat or cold
Vibration	None	Prolonged exposure
Information	Good	Unstructured
Instruction	Good	Lacking
Qualification	Regular measures	Unstructured
Supervision	Regular	Occasional
Flexibility	Employees can help design the duty roster	Rigid resource planning

Table 2: Health risks that can be increased by working conditions and work organisation

A combination of long working hours and the risks listed in Table 2 increases the potential for health problems.

In principle, long working hours can lead to fatigue, the effects of which can lead to work-relevant limitations:

- Reduction in the functioning of an organ or organism as a result of physical exercise
- Decrease in energy (power reserve)
- Disturbance of equilibrium states
- Disturbance of the regulatory and coordination mechanisms
- Decrease in job satisfaction
- Shifting the motivational structure
- Personality disorders

3.2. Impact model of long working hours:

Long working hours have a complex relationship to prolonged exposure to stress with reduced recovery times and available social time. Biographical and individual characteristics can lead to an increased accident risk, reduced performance and productivity, social and health impairments, and these conditions can influence and reinforce each other. Overriding moderating factors exert a controlling effect and influence. As stated in the WIFO Report

(Keil A., 2011), an attempt was made to estimate the costs of long working hours on the basis of an evaluation of the literature, which addressed not only the costs of illness but also social costs (Figure 2):

Impact model of the effects of long working hours:

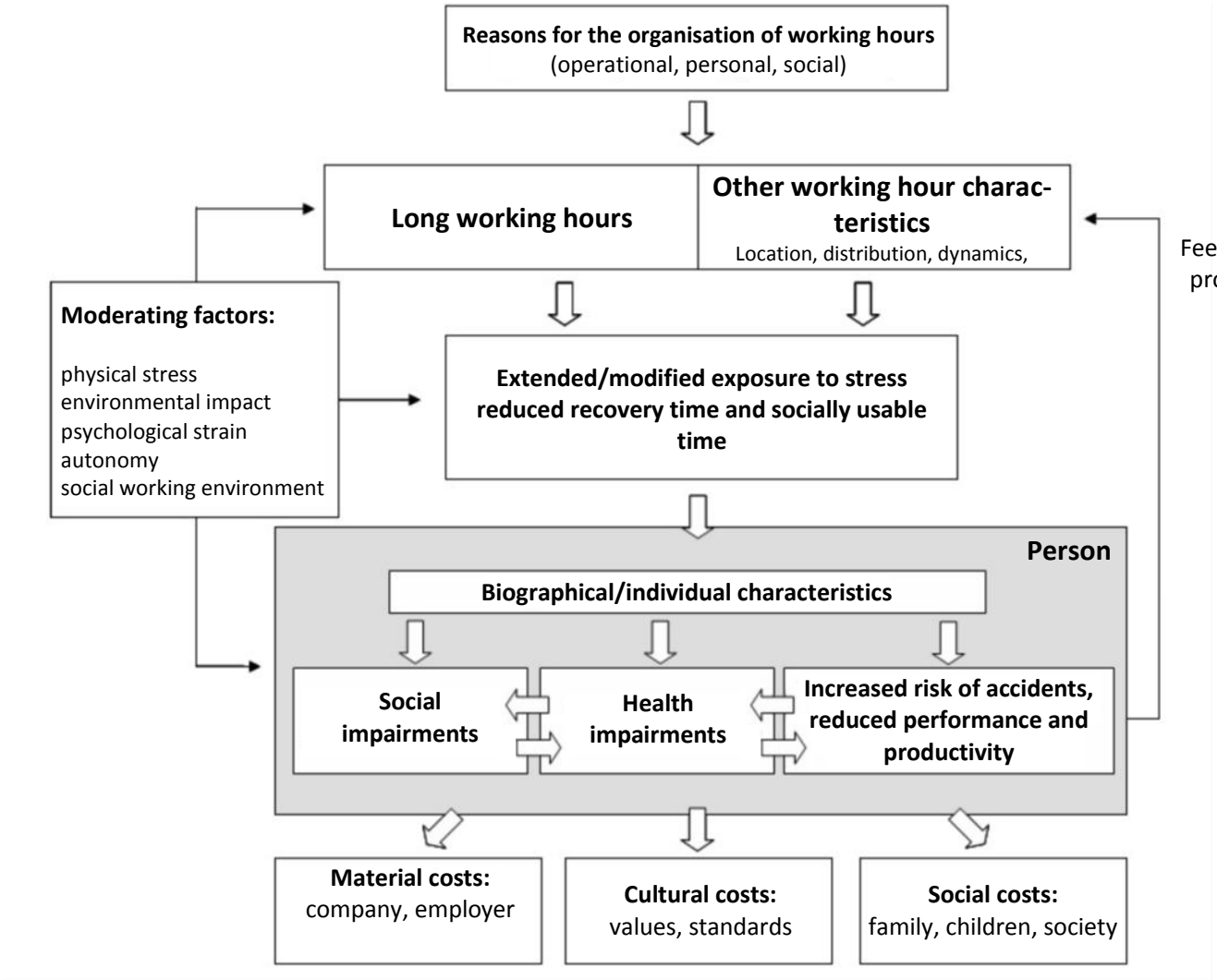


Figure 2: Impact model of the effects of long working hours according to Wirtz A., 2010

Age and workload are important factors for recovery times (Figure 3)

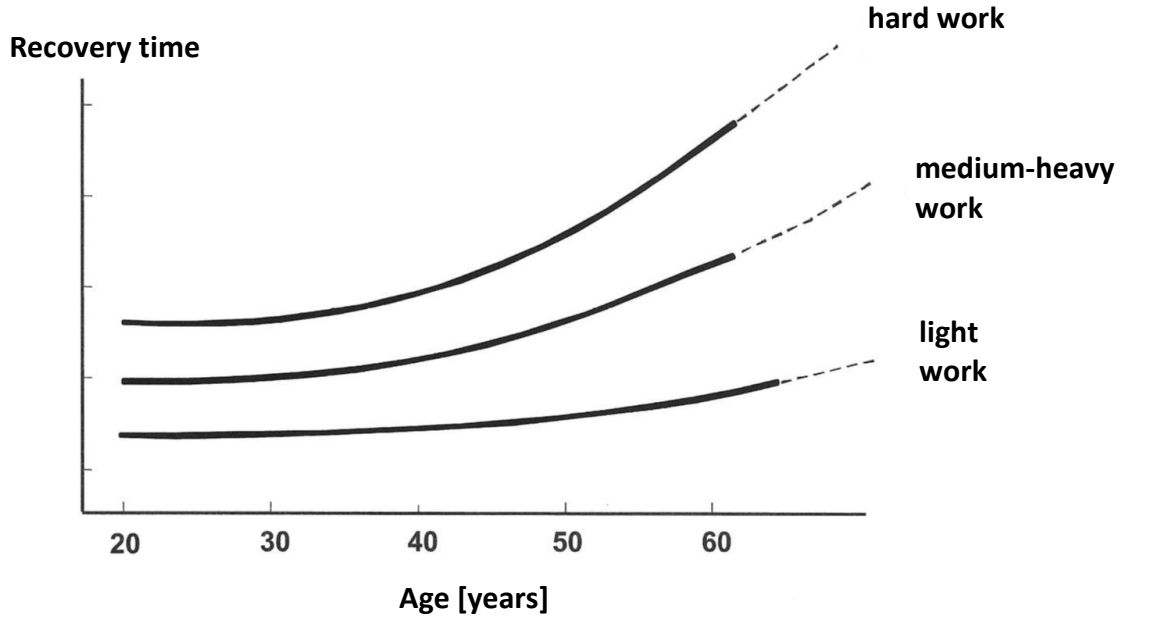


Figure 3: Recovery time depending on age and workload (Ilmarinen 1999)

4. Effects of extended maximum working hours on the risk of accidents

4.1. Evaluation of the literature:

Among the numerous effects of extended regular working hours that have been investigated, the increase in the risk of accidents, which can be caused, among other things, by fatigue or reduced alertness (Van der Hulst, 2003; Blasche, Bauböck & Haluza, 2017; Fischer et al., 2017), represents a major aspect.

The list of studies which have established an association between long working hours and an increased risk of accidents at work among employees in specific occupations and industrial sectors is long; the following is a selection by occupational group without any claim to completeness: construction workers (Lowery et al., 1998), nurses (Macias et al., 1996; Lo et al., 2016), anaesthesiologists (Gander et al., 2000), veterinarians (Trimpop et al., 2000), health care professionals (Dembe, Delbos & Erickson, 2009; Kirkcaldy, Trimpop & Cooper, 1997; Simpson & Severson, 2000), police officers (Vila, 2006; Violanti et al., 2012), mine workers (Duchon & Smith, 1994; Friedman, Almberg & Cohen, 2019), metal workers (Liu et al., 2016), bus drivers (Meijman, 1997), lorry drivers (McCartt et al., 2000; Chen & Xie, 2014a and 2014b), firefighters (Lusa et al., 2002) and nuclear power plant workers (Baker, Olson, & Morisseau, 1994). An increased risk of serious hand injuries among factory workers in Hong Kong has been found to exist when working hours are extended beyond 11.5 hours (Ong & Kogi, 1990).

In Germany, a systematic analysis of social security data for over one million employees revealed an increased risk of major accidents at the workplace after the eighth hour of a long

shift (Hänecke et al., 1998) (see also Figure 1). A recently published meta-analysis, incorporating 29 studies, was also widely regarded. It showed that the risk of accidents at work increased by about 80% for a working time of 12 hours compared to the normal working time of 8 hours (Fischer et al., 2017).

The recent result is also coherent with the included literature on the principles for the occupational health assessment of working time arrangements in 2007 originally published by the Austrian Society for Occupational Medicine (see Figure 4 below).

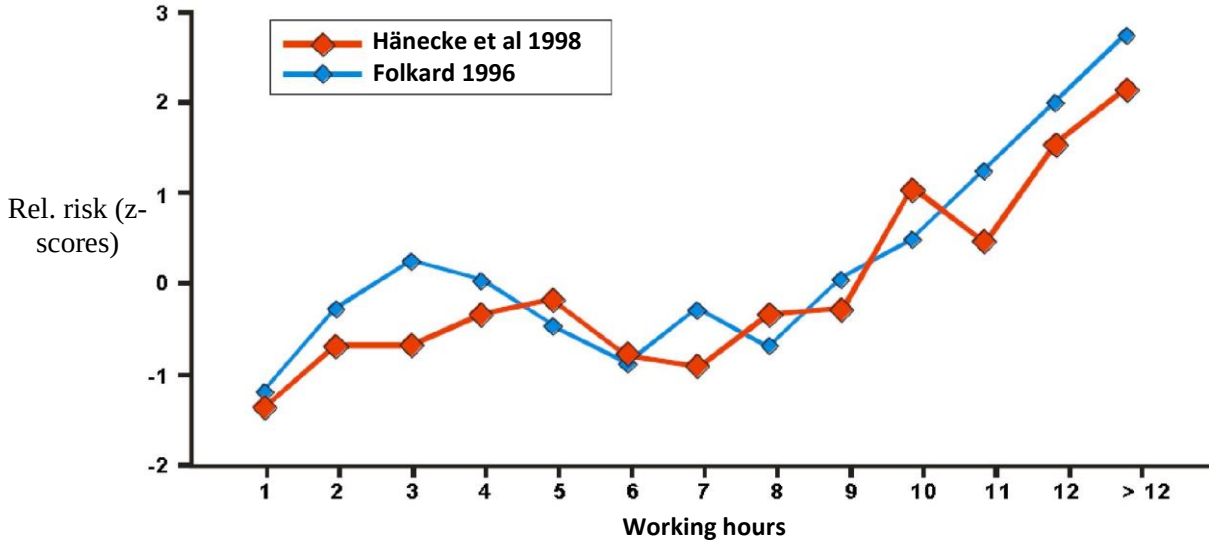


Figure 4: Relative risk of occupational accidents by hours worked per day (adapted from Nachreiner, Akkermann and Hänecke, 2000).

These results are consistent with other studies showing an increasingly higher risk of accidents in the second half of long shifts (for example, longer than 9 hours): (Shah, Barnwell & Bieler, 1997; Hänecke et al., 1998; Nachreiner, Akkermann & Hänecke 2000; Folkard & Akerstedt, 2004; Dembe et al., 2005; Fischer et al., 2017). This trend was also confirmed by a secondary analytical evaluation of three systematic studies with a large sample (Folkard & Lombardi, 2004). The risk of a fatal occupational accident increases exponentially after the 9th hour of work (Akkermann, 2001).

A study in Scandinavia found a comparable risk of injury in the workplace in the second half of long shifts (Akerstedt, 1995; Folkard & Akerstedt, 2004). The sequence and length of work shifts, as well as the length of breaks between shifts, were also identified as risk determinants for industrial accidents (Tucker, Folkard & Macdonald, 2003). The relative risk of suffering an accident in this study was twice as high in the last half hour of two hours of continuous work compared to the first.

Summarising the results of the above-mentioned scientific publications, there is a clear indication of an increased risk of work-related injuries due to longer working hours. Both the strength and consistency of the published associations support this.

Moreover, a study published by Dembe, Erickson, Delbos and Banks in 2005 provided evidence of the biological plausibility of this relationship (Dembe et al. 2005). A theoretical model presented by Michael Schuster and Susan Rhodes in 1985 was adapted for the con-

cept of the study (Schuster & Rhodes, 1985). It is assumed that overtime and long working hours increase the risk of accidents at work by influencing various intermediate factors such as fatigue, stress and drowsiness. Various individual and environmental factors play a role, including personal characteristics (e.g. age, gender, health status, work experience), work-related variables (e.g. intensity of work, exposure to hazards) and organisational characteristics (e.g. guidelines on overtime, level of supervision). This model is shown in Figure 5.

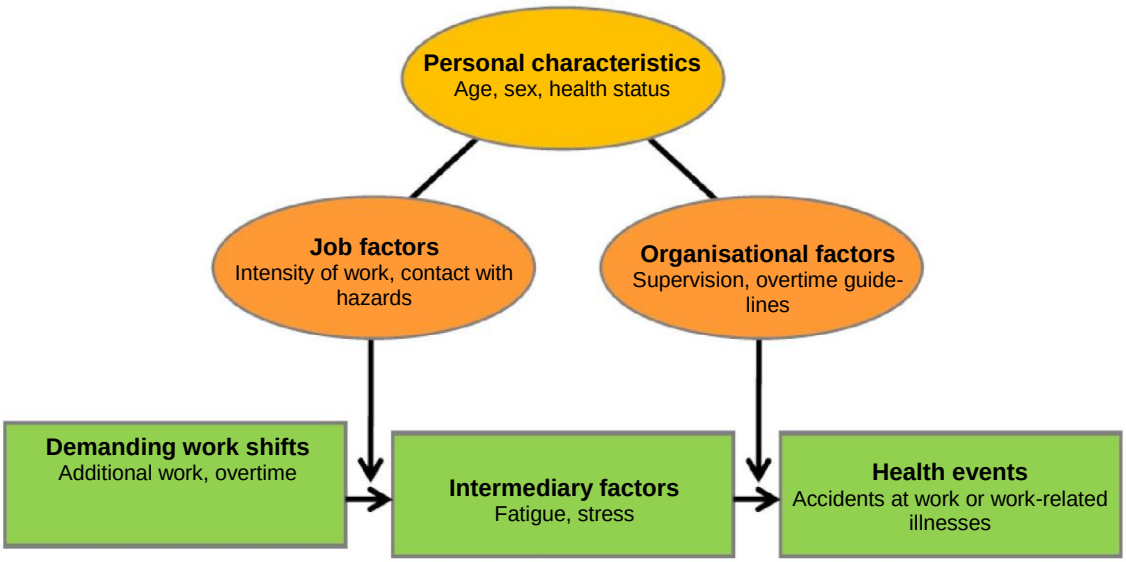


Figure 5: Biologically plausible model adapted by Dembe et al (2005).

The cited study by Dembe et al (2005) covers a period of 13 years and is based on data contained in 110,236 workplace records. Multivariate analyses were used to control the influence of age and gender of employees, region, industry and occupation. A key result of this data analysis was a clear dose-response relationship: the number of hours worked per week (> 40 hrs) and the number of hours worked per day (> 8 hrs) correlated positively with an increased accident risk. This result supports a possible causal link between working time and the frequency of accidents at work. Employees who worked overtime had a 61% higher accident risk than those whose jobs did not require overtime.

4.2. Conclusion:

The increase in the accident risk due to the extension of working hours from 8 to 12 working hours varies depending on the study; however, based on the results of the recent meta-analysis – which ultimately included 29 investigations from 97 evaluated studies – it can be assumed that the risk of occupational accidents increased by around 80% (Fischer et al., 2017). As already pointed out in the 2007 ÖGAM guideline, the causal relationship between increased standard working hours and increased accident risk is proven due to the fulfilment of epistemological quality criteria of the literature mentioned (strength and consistency of associations, biological plausibility and a dose-effect relationship).

As early as 2005, one key finding made by Dembe et al. was that, regardless of the employment sector and type of work, employees who worked overtime had a higher risk of accidents. From the point of view of occupational medicine, an extension of working hours to maximum permissible working hours of 12 hours per day and 60 hours per week is therefore questionable for sectors or occupations with an increased risk of accidents, as a higher impact on the accident rate is to be expected.

5. Increase in the incidence of illnesses during long working hours, literature analysis

5.1. CARDIOVASCULAR DISEASES

Those who worked 55 or more hours a week had a 1.3 times higher risk of suffering a stroke than under “standard working hours”. This association, presented in a meta-analysis, applied in equal measure to men and women and was independent of the geographical origin of the workers. The risk of coronary heart disease (CHD) was also increased for those with long working hours (Kivimäki M., 2017)

The study was based on published and unpublished data from 24 cohorts from a total of 25 studies in Europe, the USA and Australia. The evaluation included only prospective cohort studies that examined the effect of working hours, for which data on individual exposure levels with outcome data were available, which reported stroke events or cases of coronary heart disease, and which contained certain statistical parameters (relative risk RR, odds ratio OR, hazard ratio HR with 95% CI) or data for their calculation.

In total, the CHD meta-analysis included data from over 600,000 people who had no coronary heart disease at the start of the study. The evaluation of the stroke risk included almost 530,000 men and women who had not suffered any stroke at the beginning of the study. The median follow-up was 8.5 years for the analysis of the CHD risk and 7.2 years for the analysis of the stroke risk. During this period, 4,768 cardiovascular events and 1,722 strokes were recorded.

The statistical evaluation adjusted for age, gender and socioeconomic status showed that a weekly working time of 55 hours and more was associated with a moderately increased risk of cardiovascular events (relative risk 1.13, 95% CI, 1.02–1.26; p=0.02) and an increased risk of stroke (relative risk 1.33, 1.11–1.61; p=0.002) compared to standard working hours (35–

40 hours per week). With increasing working hours, the relative risk of stroke also increases from 1.1 (41–48 hours per week) to 1.27 (49–54 hours) and up to 1.33 (≥ 55 hours).

According to the authors, the association between long working hours and stroke is biologically plausible. It could be due to repeated triggering of the stress response system caused by overwork. Another link to the increased risk of stroke due to overtime could be physical inactivity.

A survey by the German Confederation of Trade Unions (DGB) shows how relevant the risk factor "excessive working hours" is. According to the study, 33 percent of full-time employees in Germany work 45 hours or more per week. According to the DGB's "Good Work" index, 8 percent of full-time employees have a compact weekly working time of at least 55 hours. Long working hours can increase the risk of stroke and, to a lesser extent, heart attack. According to the authors, these study results suggest that cardiovascular risk factors should be given greater attention in the case of people who work a lot.

People with long working hours have an increased risk of an irregular heart rhythm, i.e. atrial fibrillation (Kivimäki M. 2018). The analysis of data from nearly 85,500 men and women showed that those who work 55 hours a week or more have a 40 percent higher risk of developing atrial fibrillation in the next ten years. At the beginning of the studies, none of the participants suffered from atrial fibrillation. In the following ten years, there were 1,061 new cases. This corresponds to an incidence rate of 12.4 per 1,000 persons. However, among the 4,484 people who worked more than 55 hours, this figure was 17.6. The risk increased by a factor of 1.4, although factors such as age, gender, socioeconomic status, obesity, recreational sports, smoking and alcohol consumption were taken into account. Atrial fibrillation is one of the most significant causes of cerebral stroke; thus this study result thus follows on from the increased risk of stroke observed in 2014 with long working weeks (Kivimäki M. et al., 2017).

Further study results:

Whitehall II prospective cohort study (Virtanen M., et al. 2010): 6014 British officials; 11 years of observation. Increased risk of CHD, significant increase after 3–4 hours of overtime per day; independent of sociodemographic characteristics, reduced sleep, psychological stress, type A personality or common coronary risk factors

Multicohort study on atrial fibrillation and long working hours (Kivimäki M., et al., 2017). 85494 employees, significant from 55 hrs per week: Employees with longer working hours have a 40% higher risk of developing cardiac arrhythmia.

Epidemiological evidence between long working hours and health (Bannai A., Tamakoshi A., 2014): 19 studies were evaluated, significant when working > 55 hrs per week for anxiety, depression, sleep impairment and coronary heart disease.

Long working hours and venous thromboembolism (Kivimäki M., et al, 2018): > 55 hrs per week significant risk of pulmonary thrombosis, deep and superficial leg vein thrombosis

5.2. METABOLIC DISEASES

Obesity, long working hours and leisure activities (Cook M., Gazmaraian J., 2018): increased risk with lower leisure activities

Obesity, long working hours, psychosocial factors at work (Lalluka s., et al., 2013): Obesity in men associated with long working hours, not significantly associated with psychosocial factors at work.

Diabetes and long working hours and shift planning (Bannai A., et al., 2016): > 45 hrs per week sign. Risk 2.43 for shift workers, but not for normal shifts.

5.3. MENTAL ILLNESSES

Depression and long working hours (Ogawa R et al. 2018): 1241 doctors in training, 80 hrs/week; 12.2 hrs/day; significant association with depressive symptoms.

Long working hours, physical inactivity and burnout (Hu N-Ch., et al, 2016): Correlation between working hours > 60 hrs/week and burn-out; with physical activity the burn-out risk is reduced.

Long working hours and alcohol consumption (Virtanen M., et al., 2015): Long working hours > 48 hrs/week lead to a 1.13 higher risk of a new risk-associated alcohol drinking behaviour.

Long working hours and depressive symptoms, meta-analysis (Virtanen M. et al., 2018): > 55 hrs/week, 1.4-fold risk of newly occurring depressive symptoms (Asia 1.5-fold)

5.4. MUSCULOSKELETAL DISEASES

Long periods of sitting and back pain (Jorgensen K., et al., 2018): sign. increased discomfort (Blue Collar worker).

Long working hours and the health status of workers in different EU countries (Cortez A., 2013): Increase in psychosocial risks and negative changes in health outcome.

5.5. ABSENCES

Long working hours and absenteeism (Bernstrom V.H., 2018): Danish study, sign. lower absenteeism (but < 45 hours per week and employee participation in shaping weekly working hours).

6. Psychosocial effects of long working hours

The organisation of working time has a direct influence on how much time is available for rest, sleep, family activities and leisure time. So the longer the daily or weekly working hours are, the less time there is for regeneration and other activities. 12-hour shifts leave little time before and after work for personal tasks, eating and dressing, but no “real leisure time”.

After such long working days, sleep is generally shorter than the recommended 7.5 to 8 hours (Gärtner et al. 2008; Rutenfranz et al. 1993). A “real leisure time” of at least 2.5 hours per day, as recommended by Rutenfranz et al. (1993), is also no longer possible during such long working days – unless sleep is sacrificed for it (Basner & Dinges 2009).

However, long working days not only shorten the rest period, but also increase the need for recovery on days off to compensate for the workload (cf. also Blasche et al. 2017). This also

limits the possibilities for leisure activities on days off. If several long working days are planned one after the other, this leads to insufficient recovery possibilities over several days, and thus to an accumulation of fatigue and sleep deficit.

High weekly working hours can also lead to increased risks of poor work-life balance, increased stress perception and even psychological impairments. In the following, the effects of long working hours on mental health and social life will be examined in more detail in order to subsequently derive design recommendations for avoiding or reducing negative effects.

6.1. Effects of long working hours on mental health

Daily working hours

As shown above, the division into work, leisure time and sleep leads to a reduction in sleep time and leisure time with longer daily working hours. However, the studies do not necessarily provide clear evidence that long working days inevitably lead to a deterioration in (mental) health – even though other risks such as the increased risk of accidents after the 9th hour of work are well documented (see Chapter 4). Reviews of the effects of 12-hour shifts on mental health have delivered contradictory results.

Some studies find improvements, others deteriorations in health, and still others find no difference between 8- and 12-hour shifts (for 12-hour shifts in nursing, Harris et al. 2015; cross-sector investigations, Knauth 2007a).

Where negative effects of long daily working hours were found, they were mainly increased fatigue, exhaustion, stress sensation and burnout. Improvements in well-being tended to occur when the long shifts were chosen by the employees themselves and there were accompanying measures to reduce stress (see also below). The number of such long days in a row also plays an important role in the resulting stress and strain, as short or longer weekly working and rest periods occur, depending on the specific design.

Weekly working hours

The length of the working week has quite clear links with mental health. A linear correlation between weekly working hours and psychovegetative impairments (i.e. self-reported problems such as stress perception, inner restlessness, depressive mood, sleep disorders, gastrointestinal disorders) can be observed across all gainfully employed persons. The longer the working week, the more frequently these impairments are reported (Amlinger-Chatterjee 2016; Wirtz 2010). People who work more than 40 hours a week have an above-average number of complaints. Employees with long weekly working hours also report more frequent fatigue, reduced attention span and concentration, and also burnout (Amlinger-Chatterjee 2016; Caruso 2006; Spurgeon 2003). A recent meta-analysis also found an increased risk of depressive symptoms in individuals working more than 55 hrs/week (Virtanen et al. 2018). These risks tend to be found mainly in women, whereas men and people with shorter weekly working hours do not show a significantly increased risk (ibid; Virtanen et al. 2011; Weston et al. 2019).

In order to mitigate the consequences of long working hours, some of those affected also establish behaviour patterns that are harmful to their health, such as smoking or alcohol

consumption (Caruso 2006). On the other hand, long working hours often leave little time for a healthy diet and sufficient sporting activities or exercise.

6.2. The interaction of long working hours with other stress factors

Negative health effects are more likely to be observed if other risk factors are added to the 12-hour shifts, such as long weekly working hours, overtime, many long days in a row, night work and no or few breaks (Harris et al. 2015) or shared services or very many breaks, or shifts starting very early or ending very late. Also with regard to weekly working hours, factors such as the workload (e.g. high physical or mental strain), shift work with night work, work on evenings and weekends have a strengthening effect, so that people with several stressful working conditions usually report the most impairments.

An example from Arlinghaus & Nachreiner (2017) is given in Figure 6. Based on various data sources, a model calculation was made of the proportion of people without work-related health impairments ("freedom from impairments") with long working hours and with and without work on evenings and weekends. It can be seen that employees with regular evening and weekend work would have to work on average about 17 hours less per week to reach the same impairment level as people without evening and weekend work. This makes it clear that although the length of work is an important factor in stress and strain, it is also, and above all, the overall design of work (time) that must be considered.

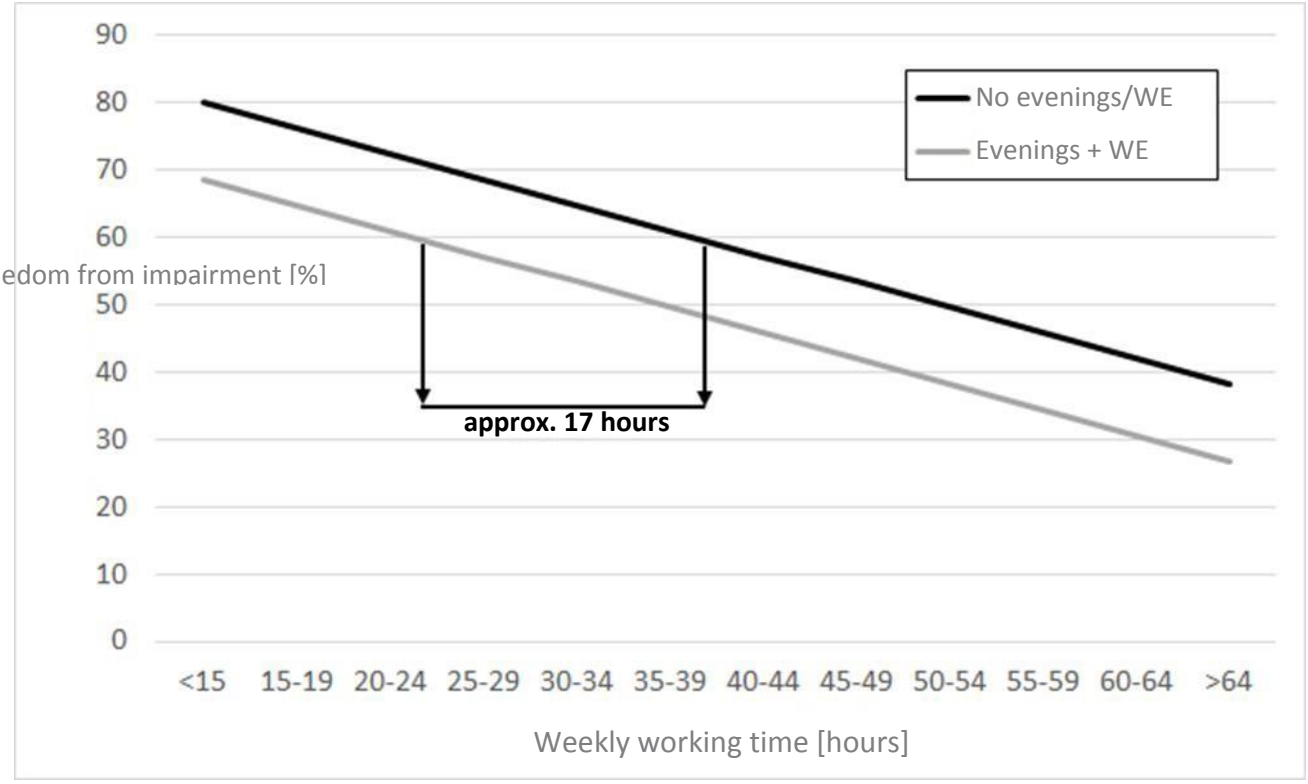


Figure 6: Percentage of employees without health impairments depending on regular weekly working hours and work on evenings and weekends (WE), from Arlinghaus & Nachreiner (2017)

Figure 7 schematically shows the interaction between daily and weekly working hours. For short daily working hours (8 or less hours during the day), the load appears to be low as long as the weekly working time is below about 40 hours a week. If the weekly working time in-

creases, more than 5 working days are necessary, which in turn allows too few days off for rest. If the daily working time is increased, clear risks occur at over 10 hours/day. If, however, the weekly working hours are limited, the risks nevertheless remain within acceptable limits (shown here in yellow-orange).

Only in the case of longer weekly working hours are working days of 10 hours demonstrably unfavourable. 12-hour shifts, on the other hand, always represent a risk if they are associated with full-time work or longer weekly working hours (red area). However, individual 12-hour shifts with low weekly working hours may be acceptable, depending on the workload and time of day.

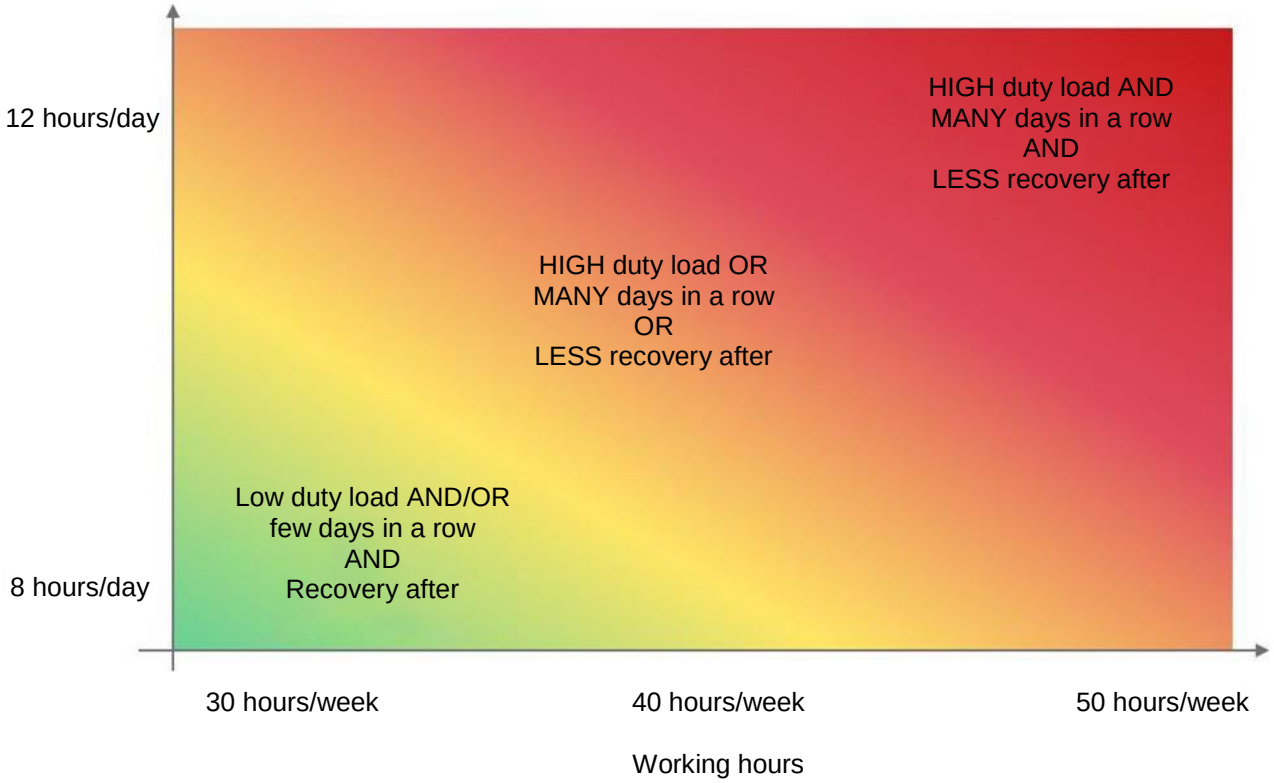


Figure 7: Stress due to the combination of daily and weekly working hours

Individual factors also work in combination with working hours: Older employees as well as people with nursing or care obligations report health problems more frequently during long working hours than younger people and persons without additional obligations besides work. Gender also seems to play a role (see above) as women seem to have more impairments during long working hours than men. Therefore, working time extensions should also take into account the affected workforce and its individual prerequisites and performance – also at a longer-term level (demographic change, extended working life if retirement age is increased).

6.3. Long working hours and work-life balance

Arlinghaus et al. (2019) discuss the effects of long working hours on the work-life balance in their consensus paper on the social effects of working time. “Work-life balance” refers to the extent to which work and private life can be reconciled. Other concepts refer more strongly to problems of reconciling work and family life, such as the “work-family conflict”. Unlike effects on health or accident risks, these kinds of social effects are less easy to measure and

are often subjective. This means that the assessment of those affected can differ greatly – even under otherwise identical conditions – depending on individual lifestyle and preferences.

Some studies show a correlation between overtime and higher work-family conflict (Albertsen et al. 2008; Jansen et al., 2003, 2004; Peters et al. 2008). As weekly working hours increase, there are also increasing reports of worsening work-life balance (Byron 2005; Michel et al. 2011; Wirtz 2010). Additional factors such as working evenings or weekends (which are more likely in the case of long weekly working hours), shift work or very irregular working hours reinforce the negative effects of long working hours. The possibility of influencing working time oneself improves the overall compatibility, but does not completely offset the negative effects of long working hours (ibid.). This means that even self-selected long working hours affect the work-life balance.

6.4. Compressed working weeks

Employees often prefer a compressed working week, for example, consisting of four days of 10 hours each. The aim is to achieve an additional day off per week that can be used for social activities and leisure. The introduction of a compressed working week for shift workers showed improvements in the work-life balance in a review by Bambra et al (2008).

Since fatigue does not seem to be increased overall by the longer working days, it can be assumed that the higher fatigue and exhaustion can be compensated by the extra day off. In the intervention studies, mental health even seems to tend to be improved by compressed working hours. However, there seems to be a combination of satisfaction with (self-chosen) compressed working hours and a better reported work-life balance that could explain the effects on mental health (see below). This means that people who choose such compressed working hours will achieve better reconciliation and satisfaction, which in turn will improve mental health.

It could therefore be argued that 10-hour shifts do not bring any significant deterioration compared to 8-hour shifts in terms of health and work-life balance, but 12-hour shifts are far more problematic (Tucker 2006).

6.5. Indirect effect of poor work-life balance on mental health

A poorer work-life balance is associated with a higher risk of psychological impairment of employees (Wöhrmann 2016), so that long weekly working hours act both directly and indirectly as risk factors for illness due to a worsening of the work-life balance. In a large-scale meta-analysis, the strongest correlation between poor work-life balance and work-specific psychological complaints such as burnout, work-related stress and personal stress was determined. An enrichment of private life through work, on the other hand, is related to improved mental health (ibid.). It can be assumed that long working hours affect employees' resources in order to cope with this increased burden. If conflicts with private life are added to this, such as problems with childcare, no time for personal interests or sports, negative effects on mental health also arise.

Employees with a poor work-life balance are, in turn, more willing to change their working hours in order to achieve a better work-life balance. An adjustment of working hours due to a poor work-life balance seems to occur faster for women than for men (Arlinghaus et al. 2019). In this respect, a selection effect can be expected for long working hours – people

who do not have major problems tend to remain in such working time models for longer periods than those who experience severe psychosocial impairments. Therefore, the actual negative effects of long working hours tend to be underestimated.

6.6. Structural recommendations

In order to limit the effects of long working hours described above and to minimise adverse effects, a number of measures are recommended, which are described below.

6.6.1 Reduce and compensate for stress and strain

In order not to increase the burden too much, it is recommended to limit the daily and weekly working hours. If it is necessary to extend working time to over 10 hours a day or 48 hours a week, long working days should only be planned individually and not several times in a row.

Following long working hours, care should be taken to ensure sufficient rest periods in order to compensate for the increased load. Even during work, breaks can be an effective means of reducing stress and the consequences of stress such as fatigue. In particular, several short breaks have proven to be favourable, e.g. a few minutes per hour if the activity permits (see Knauth 2007b; Wendsche & Lohmann-Haislah 2016). Despite the "lost" working hours, constant or even increased productivity rates are recorded; so that these short breaks are worthwhile even if they are counted as working time.

After two 12-hour shifts, at least two days off are usually necessary to restore fatigue to normal levels (Blasche et al. 2017); so free time between work assignments plays an important role.

Night work as well as work on evenings and weekends represents an increased strain and requires additional rest (Kundi in Gärtner 2008).

A further approach to reducing the burden is to compensate or balance the burden (e.g. additional work, overtime) with additional free time (Gärtner et al. 2018; Arlinghaus & Nachreiner 2017) instead of financial bonuses and allowances.

However, the measures described above presuppose that sufficient personnel is available and that there is no shortage of personnel. This makes the measurement and calculation of personnel requirements an important factor in the design of healthy and socially acceptable working hours.

The duration of working time should also not be considered independently of the burden of the activity itself and other characteristics of working time. If the activity is physically, mentally or emotionally burdensome, long working hours increase this strain and stress disproportionately strongly. In the case of high workloads, an extension of working hours should therefore be dispensed with.

6.6.2. Strengthening resources

In addition to reducing stress, measures can be taken to strengthen the personal resources of employees. Personal influence on the organisation of working time (e.g. through flexitime, the choice between several working time models or shift plans, or the possibility of being

able to take time off at short notice) is an important building block for improving satisfaction, health and work-life balance. Although it does not replace good working time management, it is an important preventive measure – also for attracting and retaining qualified specialists.

Work that is flexible in terms of time and location (e.g. mobile working, home office, teleworking) can be a further component in increasing the influence of employees. However, this can only work if the technical conditions are met, the activity is suitable for mobile work and the company culture is characterised by mutual trust on the part of managers and employees.

Employees should also be included in the (re)design of working time models in order to increase the acceptance of such models. Furthermore, working hours should be planned as long in advance as possible so as not to impair the compatibility of work and private life.

At an individual level, information and training on health-conscious behaviour can be used to inform employees about the risks of working unfavourable hours they have chosen themselves and to communicate expectations, e.g. regarding availability outside regular working hours. This can be particularly useful for employees acting very autonomously in order to reduce the risks of (partly self-selected) delimitation and "self-exploitation". In the case of frequent mobile work or home office, the demarcation between work and private life is also important for many people in order to be able to "switch off" properly after work.

6.6.3. Corporate culture and leadership behaviour

A company culture should be promoted in which long working hours (e.g. culture of presence, excessive overtime) are not systematically supported. Career opportunities should also be open to people with a smaller workload (e.g. full-time without overtime or part-time work) and attention should be paid to the health effects of long working hours.

When determining working hours, account should also be taken of company demographics, since older employees are often less resilient. In addition, life-phase-oriented working hours with phases of higher and lower weekly working hours offer better opportunities to combine work and private life. Here, too, care should be taken to ensure that the phases with longer working hours do not lead to an overall excessive burden.

Regular health and employee satisfaction evaluations may provide important information on how working time is managed and its impact.

6.4. Summary and outlook

Long daily and weekly working hours can increase the risk of mental health problems and a poor work-life balance. In particular, working days with more than 10 hours and working weeks with well over 40 hours can be identified as risk factors. Other stress factors such as night work, work in the evenings and at weekends and short rest periods further increase the psychosocial risks. In the organisation of working time, care should therefore be taken to ensure that long working days only occur infrequently, are not combined with stressful activities or working conditions, and are accompanied by measures such as longer rest periods and employee influence over the organisation of working time.

7. Specific workloads with a limiting effect

7.1. Physical workloads

7.1.1. (Heavy) physical labour

The basis for the assessment of the workload is the consumption of work calories, whereby there is a direct gender relation between women and men. The work energy turnover (WT) is calculated as follows:

$$WT_{Total} = WT_{posture} + WT_{body\ movement} + WT_{activity}$$

It is based on a process study in which the individual physical activities have to be analysed. The next step is to determine the working turnover WT_i from the partial works i from tables (e.g. from Hettinger, Spitzer, Kaminski; or www.institut-aser.de). The 3rd step is to calculate the energy consumption E_i for the partial works i: $E_i = WT_i \times t_i$. By adding up the individual energy consumptions of the partial works, the average work energy turnover is obtained. Due to little experience with the factor "long working time" and the observable health impact of heavy work on health, these activities should not be carried out without precise analysis

The continuous power limits for dynamic work are given in Table 3 below.

Dauerleistungsgrenze	kJ/min	Watt (8h/Tag)	Watt (12h/Tag)
Frauen	11,0 – 12,0	180 - 200	126 -140
Männer	16,5 – 17,5	275 - 295	192,5 – 206,5

Table 3: Continuous performance limit (CPL) for dynamic work; for 12 hrs/day the CPL is reduced by 30%

The continuous performance limit indicates that if the output falls below it, a physical load is tolerated without additional rest breaks and without health damage; if it is exceeded, corresponding recovery allowances are required. These can be calculated according to this formula.

$$EZ = 1{,}9 \cdot \left(\frac{t_{Arb}}{t_0}\right)^{0{,}145} \cdot \left(\frac{AU_{eff}}{AU_{DLG}} - 1\right)^{1{,}4} \cdot 100(\%)$$

RA (recovery allowance in % of activity)
t_{work} (working time of partial work)
WT_{eff} (work done in W)
WT_{CPL} (continuous performance limit)

In order to estimate the stress as an example, the working pulse can be determined; this will be necessary if predominantly static muscle work is performed.

A limitation of the working time must be made if:

- The muscle work would be too heavy (WT >> WT_{CPL}).
- The speed of movement would not be optimal in dynamic muscle work (see example in the appendix)
- The ratio of muscle relaxation time to contraction time would be too small.
- The dynamic muscle work would contain additional static components.
- Static muscle work would be present.

7.1.2.1. Manual load handling

In addition to the severity of the work, manual load handling represents a particular health-related stress factor for the musculoskeletal system, where, in addition to acute illnesses (e.g. fractured vertebrae, herniated discs), chronic work-related illnesses in particular are caused by stress. In the assessment, it is not only the load weight that is decisive, but also factors such as body position, rotation, lifting height, frequency, handle coupling, acceleration and the type of load (Figure 8).

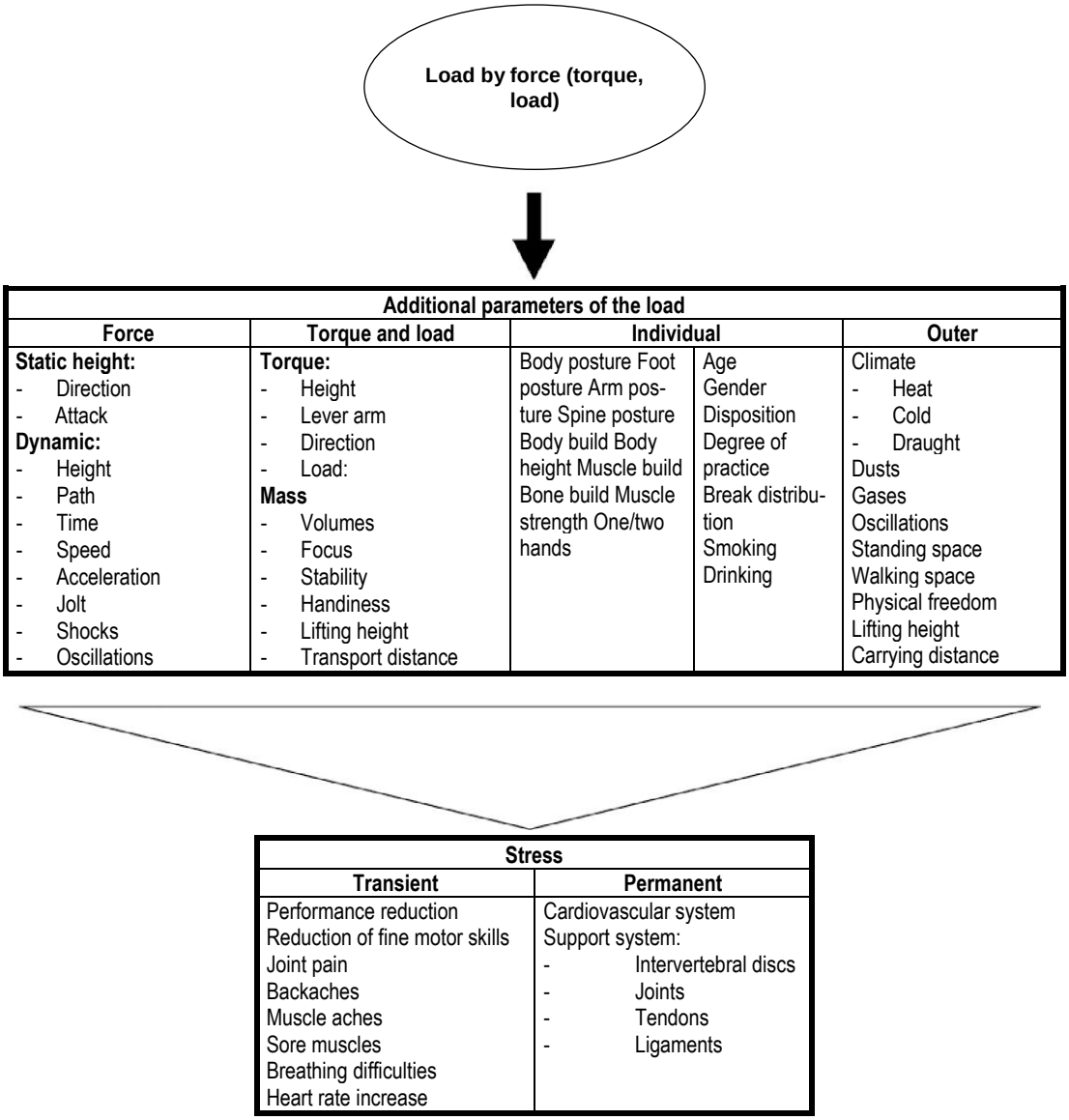


Figure 6: Load and stress factors due to the application of force (Hecker R., 1998)

The following methods are used for the evaluation in Europe:

Control characteristic method (see www.baua.de): the advantage lies in the simplicity of the application, whereby not only lifting and carrying activities can be evaluated, but also pushing and pulling actions under load. The disadvantage is that here the time factor is limited and is geared to an 8 hr day. Longer working shifts can only be referred to imprecisely. The evaluation criteria are the number of points determined and their assignment to a risk scale.

NIOSH formula (see http://www.institut-aser.de/538.htm): This assessment refers to workplace dimensions and asymmetry angle, frequency and shift time. The lifting index is evaluated (> 1 is a health risk). The posture itself is not evaluated additionally.

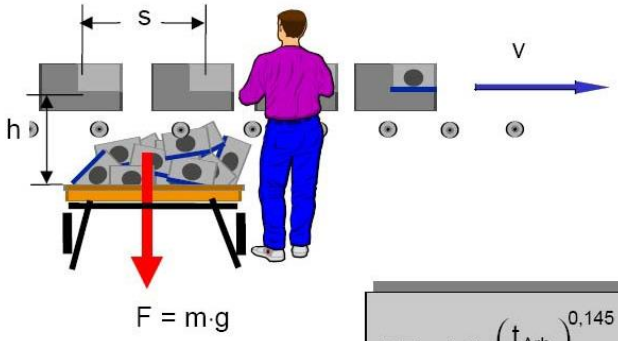
Evaluation according to EN 1005 part 2 (see http://www.institut-aser.de/538.htm): The evaluation procedure is similar to the NIOSH evaluation, the evaluation criterion is the "risk index" (> 1 means a risk).

Controlling characteristics method for recording loads in manual work processes (see www.arbeiterkammer.at/publikationen): This procedure is used for an orienting assessment of physical stress.

An assessment of the load manipulation during the assessment must be obligatory, since with longer working hours the "dose" and thus also the risk – apart from fatigue – for an work-related illness increases strongly.

Case study "Evaluation of the work intensity"

Recovery time for dynamic muscle work above the CPL



m = 15 kg
h = 0,7 m
v = 0,3 m/s
s = 1 m

AU = 350 W

$$EZ = 1{,}9 \cdot \left(\frac{t_{Arb}}{t_0}\right)^{0{,}145} \cdot \left(\frac{AU_{eff}}{AU_{DLG}} - 1\right)^{1{,}4} \cdot 100(\%)$$

$$= 1{,}9 \cdot \left(\frac{20}{1}\right)^{0{,}145} \cdot \left(\frac{350}{285} - 1\right)^{1{,}4} \cdot 100$$

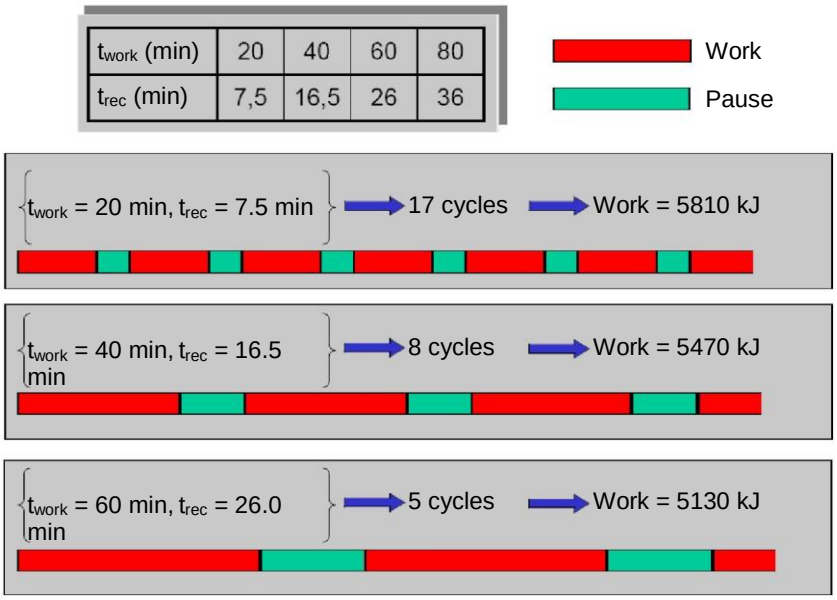
$$= 37\ \%$$

$$t_{Erh} = t_{Arb} \cdot \frac{EZ}{100} = 20 \cdot 0{,}37 \approx 7{,}5\ \text{min}$$

m Mass (15 kg) v Belt speed h Lifting height s Travel

If an employee moves a working weight of 15 kg from a pallet onto a 70 cm conveyor belt at a speed of 0.3 m/sec, this results in a working energy conversion of 350 watts. The dynamic work is above the continuous output limit of approx. 285 W (for 8 hrs; for 12 hrs: 200 W). It is therefore imperative to introduce rest breaks. If 20 minutes are worked, the required rest period is 7.5 minutes; if 80 minutes are worked, the required rest period is 36 minutes. With a CPL of around 200 W (based on a 12-hour shift), the recovery allowance would already be around 200%!

Work performed under different working-time break regimes



In a 12 hr shift, there is no longer any sensible and economically justifiable break regulation. For women and men, no heavy work would be performed under the Heavy Workers Regulation. However, a reduction of the workload is necessary, the aim being to undercut the continuous performance limit. In terms of calorie consumption, heavy work during 12-hour shifts is not justifiable from an occupational health point of view and cannot be carried out without causing damage.
Source: Ergonomics Script TU Munich 2005

7.2. Repetitive work

7.2.1. Posture during repetitive activity:

In general, there is an ***elevated*** health risk with a bent body position of 20°–60° for between one and four hours, a ***greatly increased*** health with a bent body position of 20°–60° for longer than four hours.

Comfortable postures should be performed for more than ten minutes, e.g. standing with arms at chest height within 25–50% of the reach.
Moderately comfortable postures should be performed for between 5 and 10 minutes and involve standing with arms stretched forward at shoulder height or slightly forward inclined postures up to 30°. The arm height must be limited to the horizontal shoulder height.

Uncomfortable body postures are to be performed for less than five minutes and concern, for example, overhead work and squatting with arms close to the body and at the same distance from the body (Hartmann B. 2000; see also ISO 11226 Ergonomics – Evaluation of static work postures). The latter posture will generally not be suitable for long work shifts, and the urgently needed recurring breaks will counteract the desired economic effect, as the work performance will not increase significantly as a result.

7.2.2. Repetitive hand-arm work:

Repetitive hand-arm work exists when repetitions of cyclic contractions of the same muscle by the same movement patterns are required over a certain period of time. There is an ***aggravated risk*** of musculoskeletal disorders when the cycle duration of a single action to be repeated:

- is less than 30 seconds, or
- more than 50% of the total duration of the activity and the frequency of repeated movement exceeds the values of
- 2.5/min for the shoulder
- 10/min for elbow and hand
- 100 to 200/min for the fingers

(according to Silverstein et al., 1986 and Kilbom A., 1994)

One problem with long shifts is when terminal positions are usually carried out in the end range of a joint's mobility or high force exertion in relation to maximum forces (more than 15% of the standard reference, see also EN 1005-3:2002 Recommended force limits for the operation of machinery). When assessing manual arm work, the small and large gripping space must be taken into account. Further assessment procedures can be found in the standard prN 1005-5:2003 – Risk assessment for repetitive activities at high handling frequencies.

7.2.3. Standing workstations:

Workspaces where standing is the typical physical requirement for at least 2/3 of the working hours are called "standing workstations". This results in complaints and diseases of the musculoskeletal system as well as circulatory disorders and varicose veins of the lower extremities. Since longer, standing activities lead to haemodynamic changes in the blood flow in the aorta and the formation of shear forces, there is also a risk of arteriosclerosis in these blood vessels during longer standing activities.

For long working hours, it is therefore necessary to avoid the need for constant standing, to design mixed workplaces (standing for less than 50% of the working shift) and to reduce the standing load by means of suitable standing/sitting aids. Other necessary measures include cushioned work shoes, damping floor mats in the standing area and breaks, which allow a sitting position with the possibility of raising the legs.

8. Adaptation of limit and reference values to extended working times

In principle, an extension of the daily working time beyond 8 hours is problematic in the presence of exposures which are regulated by the limit values of the LVCR, VOLV, VOPST, VEMF or NSchG and for which these exposures are at a relevant level and should be avoided as far as possible. If, however, an extension of working time is unavoidable – be it in the context of shift work, blocked working hours or overtime – then the limit and guide values must be adjusted accordingly, taking account of the respective exposure and its health effects.

The adjustment of the limit and guide values should ideally be based on the knowledge of mechanisms of action, half-lives, cumulation risks, etc. However, knowledge of such influ-

encing variables is often incomplete, which is why the Central Labour Inspectorate, in its **decree BMASGK-461.308/0002-VII/A/4/2019**, provided for a simplified procedure for adapting limit values in accordance with the LVCR system. In this guide, we follow the guidelines of the ZAI *(Central Labour Inspectorate)*, especially since in most cases it leads to lower limit values.

8.1. Exposure to noise

Annex A of the VOLV *(Ordinance on Noise and Vibrations)* contains formulae for conversion for exposures whose assessment period differs from 8 hours per day or 40 hours per week. The value of the actual exposure duration is normalised to 8 hrs/day or 40 hrs/week and can then be directly compared with the exposure limit value or action value.

The formula for noise in Annex A is as follows:

$$L_{A,EX,To} = L_{A,Eq,Te} + 10\log({}^{Te}/_{To}) \qquad \text{Equation (1)}$$

The A-weighted continuous energy-equivalent sound level related to the standard time "To" (8 hrs/day or 40 hrs/week in the case of highly variable daily exposures) is shown on the left-hand side and the level related to the actual working time "Te" plus the term for conversion to standard time is shown on the right-hand side.

This formula is based, on the one hand, on the fact that the hearing loss increases linearly with the logarithm of the exposure time and, on the other hand, on the fact that two sound situations, of which one has no effect in time (Te-To), while in the other the energy-equivalent continuous sound level LA,Eq,Te is also present in this time (Te-To), differ exactly by the second term on the right side of equation (1).

As long as the exposure limit value is respected, this adaptation does not pose a further problem. Since the duration of the hearing recovery depends only on the level of the threshold shift, the duration of the hearing recovery remains the same. However, if the exposure limit is exceeded, the hearing recovery will be extended by about 10log(16/(24-Te)) and a complete recovery may not be possible during the 24-Te rest period. Therefore, an extension of working time in the event of non-compliance with the exposure limit value must be rejected.

Let us assume that the A-weighted energy-equivalent continuous sound level at a workstation is 84 dB for 8 hours. There are no adjustments for tonality or impulsiveness and no exposure to ototoxic substances. Now the daily working time is to be extended to 12 hours, whereby the same sound situation is given in the extended working time. It therefore follows:

$$L_{A,EX,8hrs} = L_{A,Eq,12hrs} + 10\log\left(\frac{12}{8}\right) = 84 + 1{,}76 = 85{,}76dB$$

Therefore, the exposure limit value is exceeded and all measures provided in the VOLV for exceeding it must be taken.

One can also express this in reverse: In order not to exceed the exposure limit value, the LA,Eq,12 hrs must remain below 85-1.76=83.24 dB.

The question arises as to whether tonality or impulse adjustments must also be increased. Since the ototoxic effects of narrowband or impulse noise are also more serious when the exposure time is extended, it is justified to also increase the allowance by the value 10log(Te/To) (however, the ZAI decree does not provide for any regulation in this regard).

8.2. Exposure to vibrations

The VOLV also provides for an adaptation for exposure to hand-arm and whole-body vibrations (sections 2 and 3 of Annex B). In the case of the effect of accelerations on the tissue, the time dependence of the tissue stress is approximately a root function of the duration of the effect. Therefore, the VOLV provides for a correction according to the root of the ratio of the actual exposure time Te to the reference time To (=8 hrs).

$$a_{hw,8hrs} = a_{hw,Te}\sqrt{\frac{Te}{8}}$$

$$a_{w,8hrs} = a_{w,Te}\sqrt{\frac{Te}{8}}$$

Formula (2)

On the left-hand side is the acceleration value for the hand-arm (hw) or whole-body vibration (w) converted to an 8-hr duration, on the right-hand side is the acceleration measured during Te, the actual operating time.

Let us assume that a whole body value of aw,8h = 1.25 m/s² is measured for a forklift truck. According to formula (2), in order to comply with the limit value of aw,8h=1,15 m/s², the operating time for this forklift truck is (1.15/1.25)²=84.64% of the working time of 8 hrs, i.e. only 6¾ hrs. If the working time is extended to 10 hrs, the value converted to 8 hrs according to formula (2) is 1.25*√10/8=1.4. The proportion of the working time of 10 hrs in which the forklift truck may be used is reduced to 67.7%, but the absolute working time remains the same as for 8 hrs, of course. We can see from this example that an extension of the working time hardly makes sense if the exposure limit value is exceeded, because the operating times on the equipment cannot be extended.

8.3. Exposure to hazardous working substances

In the case of workplace exposures regulated by the LVCR system, it is not possible to refer to existing regulations on adaptation to extended working hours, as is the case with the VOLV. In principle, exposure to harmful substances not only poses the problem that more of the substance can be absorbed by the employee during longer working hours, but also the problem that a longer work break may be necessary to eliminate the substance and for regeneration. Both aspects must therefore be taken into account when considering any adaptation of the limit values.

The working substances regulated in the LVCR with threshold limit values can, in principle, be characterised according to their half-life and whether they are only local irritants or mainly cause odour problems. However, toxicological research has not only revealed major uncertainties in the derivation of half-lives, where individuals can vary considerably (where data is available for humans at all), and that many substances to which only local effects have previously been attributed may also be systemically effective. The ZAI's approach, which is based on the Brief and Scala (1975, 1986) proposal, therefore makes sense. However, Brief and Scala proposed their approach in the event that sufficient half-life data are not

available.

The concept is based on the assumption that, assuming that the accumulation is proportional to the duration of exposure, the 8-hr limit value must be reduced by the factor Te/8 (Te the extended daily working hours) so that the same safety margin can also be applied to the working hours Te. This reduction corresponds to Haber's rule. However, it should be noted that, at the same time, the time for excretion and regeneration of the substance is reduced by a factor of (24-Te)/16. Therefore, Brief and Scala's proposal is to apply both factors to the threshold limit value (daily mean), which gives the following overall (formula 3):

$$TLV = TLV_{8hrs}\frac{8}{Te}\frac{24-Te}{16} \qquad \text{Formula (3)}$$

Strictly speaking, the Brief and Scala proposal (1975, 1986) applies only to mean half-lives (2–8 hrs), but as we will show, the application also results in a conservative reduction for longer half-lives. For longer half-lives (but less than approx. 400 hrs) you can also use the weekly working time or the monthly working time (formula (4)).

$$TLV_{Te} = TLV_{8hrs}\frac{40}{Te\cdot w} \quad Weekly\ working\ hours\ (w\ working\ days\ per\ week)$$
$$TLV_{Te} = TLV_{8hrs}\frac{170}{Te\cdot m} \quad Monthly\ working\ hours\ (m\ working\ days\ per\ month) \qquad \text{Formula (4)}$$

According to Hickey and Reist (1977) and Armstrong et al. (2005), in more complex working time models that deviate from standard working time in terms of more than just the daily working hours, the individual components can be considered according to formula (5). But generally, the Brief and Scala proposal leads to higher reduction factors.

$$TLV_{Te} = TLV_{8h}\frac{1-e^{-k\cdot 8}}{1-e^{-k\cdot Te}}\frac{1-e^{-k\cdot 120}}{1-e^{-k\cdot(Te+Tr)*m}}\frac{1-e^{-k\cdot Ts}}{1-e^{-k\cdot 168}}\frac{1-e^{-k\cdot(Te+Tr)}}{1-e^{-k\cdot 24}} \qquad \text{Formula (5)}$$

Te denotes the extended daily working hours, Tr the rest between the m shifts of a work cycle, Ts the total length of the work cycle in hours. k is the elimination constant, which results from the half-life $t_{1/2}$ according to $\ln(2)/t_{1/2}$.

For purely accumulative substances, an even stronger reduction can be applied (formula 6):

$$TLV_{Te} = TLV_{8hrs}\left(\frac{8}{Te}\right)^2 \qquad \text{Formula (6)}$$

In addition, the Brief and Scala proposal does not apply to working hours exceeding 24 hours or to exposure to certain irritants whose harmful effects do not increase linearly (in the vicinity of the threshold limit value) with the dose (e.g. ozone).

An analogous reduction of the limit value must be applied to technical reference concentration values, although it must be stressed even more clearly that the minimisation require-

ment applies irrespective of any adjustment of the limit value.

No adjustment is to be made for the short-term values provided for in the LVCR system or for the duration and frequency of exceedances. Even in the case of longer working hours, the duration and frequency of exceedances may not exceed the values specified in the LVCR system.

Table 1. Proposal for the determination of reduction factors (RF) taking into account the time frame of the effect

Limit value	Time frame of the effect	Effect	Examples	RF
Mow	Fast/immediate	Acutely toxic	Methyl isocyanate	1
STV	Fast/immediate	Acutely irritating	NO_2, SO_2, ammonia	1
DMV	Medium slow (days)	Respiratory irritant, narcotic	NO_2, SO_2, ammonia, CO, styrene	F (3)
DMV	Slow (months, years)	Cumulative irritant or disease, carcinogenic	Ni, Pb, quartz dust, asbestos, welding fumes, diesel exhaust gas	F (4) or F (6)
DMV	Unknown			F (3)

F (3) etc. refers to the formulas in the text

Assuming a workplace is exposed to sulphur dioxide. If there are no additional loads such as suspended particulate matter, which can lead to an increase in effect, the threshold limit value for SO_2 can be adjusted according to formula (3).
The LVCR system contains the following information:

Substance	CAS	TLV or TRC	Toxic to reproduction	Carcinogenic	Limit value						H, S	Reference or comment
					DMV		STV		Duration [min]	Frequency per shift		
					[ppm]	[mg/m³]	[ppm]	[mg/m³]				
Sulphur dioxide	[7446-09-5]	TLV			0.5	1.3	1	2.7	15(Miw)	4x		

If there is now a working time of 12 hours, the threshold limit value is halved according to formula (3). This means that it is then 0.25 ppm or 0.65 mg/m³.

If, for example, workers are exposed to cadmium during battery production, then the long half-life of several years and accumulation in kidneys and liver must be taken into account. The TRC value is 0.03 mg/m³.

Substance	CAS	TLV or TRC	Toxic to reproduction	Carcinogenic	Limit value						H, S	Reference or comment
					DMV		STV		Duration [min]	Frequency per shift		
					[ppm]	[mg/m³]	[ppm]	[mg/m³]				
(e.g. cadmium chloride, cadmium oxide, cadmium sulphate, cadmium sulphide)	[10108-64-2] [1306-19-0] [10124-36-4] [1306-23-6]	**TRC**										
- Battery production, thermal zinc, lead and copper recovery, welding of alloys containing cadmium						0.03 E		0.12 E				
- others						0.015 E		0.06 E				

Here we apply formula (6) because of the extremely long half-life and accumulation in the kidneys and liver. If the working time is extended to 10 hours per shift. The result is an RF=0.64 and thus a corrected threshold limit value of 0.0192 mg/m³.

In the production of phenylsiloxanes, workers are exposed to chlorobenzene by inhalation. Chlorobenzene has biphasic degradation kinetics with different half-lives, but it is always longer than 8 hrs in total. Therefore, formula (4) can be used for the weekly working hours.

Substance	CAS	TLV or TRC	Toxic to reproduction	Carcinogenic	Limit value						H, S	Reference or comment
					DMV		STV		Duration [min]	Frequency per shift		
					[ppm]	[mg/m³]	[ppm]	[mg/m³]				
Chlorobenzene	[108-90-7]	TLV			5	23	15	70	15(MiW)	4x		

According to the LVCR, the TLV is 5 ppm or 23 mg/m³. If the weekly working time is extended to 55 hrs, the RF=0.73 and the adjusted TLV is therefore 3.6 ppm or 16.7 mg/m³.

If we apply formula (5) for more complex working time systems, we see that the reduction factor RF does not always decrease with increasing half-life. The following Figure 9 shows that with a prolonged leisure period the RF increases again from a certain half-life. However, the Brief and Scala formula always remains conservative at 0.5 if the working time is extended to 12 hours.

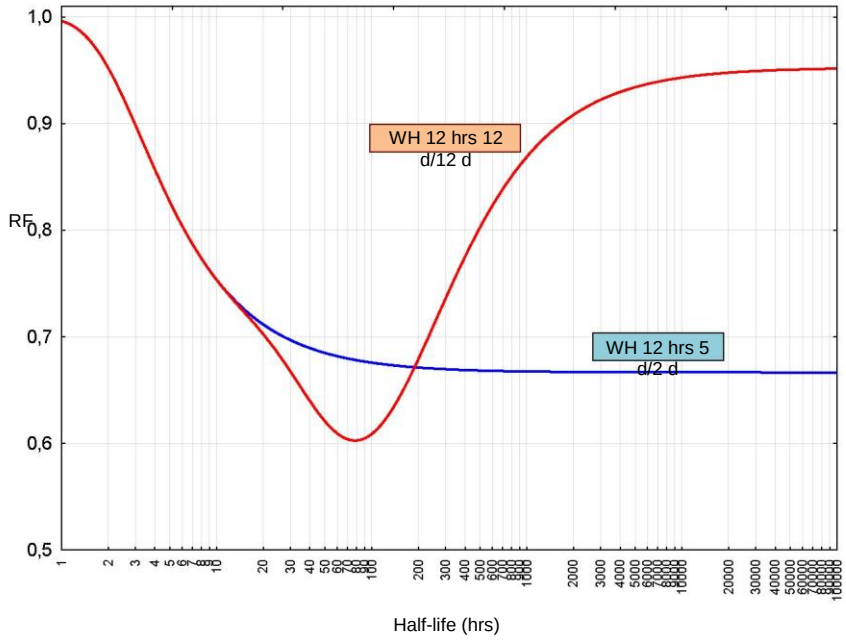


Figure 9: The dependence of the reduction factor (RF) on the half-life and the number of working and free shifts according to formula (5) from Hickey and Reist (1977). In both cases, however, the working time is 12 hours, in one case 5 working shifts and 2 days off, in the other case 12 working shifts and 12 days off

Table 4 below shows that the Brief and Scala formula generally produces the largest reduction.

HL / WH/adjustment	5 hrs	8 hrs	65 hrs	450 hrs	infinitely
8 hrs	100	100	100	100	100
12 hrs/without adjustment	128	126	118	116	105
12 hrs/Brief & Scala (3)	64	63	59	58	52
12 hrs/Hickey & Reist (5)	106	98	81		
12 hrs/Haber	85	84	79	78	70
12 hrs/accumulative (6)				52	47

Table 4: Ratio of the cumulative concentration of pollutants in the organism of exposed workers as a percentage of the concentration occurring during 8 hr shifts (5 days work/2 days off), if the working time is extended to 12 hrs, depending on the half-life (HL).

8.4. Carcinogenic agents

There are no threshold values for carcinogenic substances with genotoxic effects; the limit values are defined as technical reference concentrations (TRC values). However, compliance with these limit values cannot reliably rule out the possibility of illness, so these values must always be kept well below them, especially carcinogenic substances in categories A and B of the Limit Value Concentration Regulation (LVCR). If there are no reasons for exclusion (closed systems), frequent TRC value checks shall be performed. In principle, the substitution requirement must also be given priority here.

The use of carcinogenic agents is subject to special legal provisions of the ASchG *(Employee Protection Law)*, the implementation and efficacy of which must also be evaluated. Special attention should be paid to chemical intermediary products such as nitrosamines in the use of cooling lubricants or pyrolysis products, which may have a carcinogenic potential under certain conditions (e.g. lack of maintenance, exhaust air deficits).

8.5. Sensitising agents:

With the frequency of exposure to sensitising agents, the risk of illness increases. Furthermore, there are influencing factors such as moisture damage to the skin, unprotected skin contact or processing temperature with increased volatility of the working substance. These factors significantly increase the risk of sensitisation regardless of concentration in the workplace. The evaluation should therefore pay particular attention to the procedure and the framework conditions, as the time factor increases exposure.

8.6. Biological agents

Biological agents, especially unintentional biological exposures, behave similarly to sensitising substances. Long shifts increase the possibility of contact and thus the risk. A quantitative statement for long working shifts is currently not possible with certainty, but the evaluation focuses on structural measures to effectively limit exposure. When personal protective equipment is used, it must be assumed that it is to be assessed as an additional burden and

cannot normally be used over a long working shift.

8.7. Exposure to optical radiation

In workplaces where incoherent or coherent radiation occurs, which are subject to the VOPST regulations (*Ordinance on Optical Radiation*), corrections to the limit value are generally also necessary. This concerns the following cases:

- Incoherent radiation in the UV-A, UV-B, UV-C range (VOPST, Table A.3 lines a,b). The limit values refer to 8 hrs
- Coherent radiation (laser radiation) (VOPST, Table B4.c). The exposure limit values refer to a maximum duration of 30000 s (8 hrs 20 min).

Furthermore, it must be noted that lamps of the risk group R0 (VOPST, Table A.4) are only considered safe up to an irradiation period of 8 hrs 20 min. If the irradiation takes place beyond this time, an evaluation is necessary, whereby the irradiance of the lamps at the respective workplaces is to be measured.

For all other cases not mentioned above, the exposure time is only allowed for a short time. These times must not be exceeded, irrespective of the duration of the working time, and such effects may only occur once per shift.

Since the Bunsen-Roscoe principle applies approximately to the exposure to optical radiation, the radiation intensity must be reduced proportionally when the exposure time is extended in order to keep the dose constant. It therefore follows:

$$E_{Te} = E_{Tmax} \frac{Tmax}{Te} \qquad \text{Formula (7)}$$

If the working time exceeds Tmax, the maximum exposure time according to VOPST, an adjustment must be made by applying formula (7).

Worker are exposed to incoherent UV-A radiation during their entire working time. This case is limited by Table A.3, row b of the VOPST with an exposure limit value of 10^4 J/m² related to 8 hrs. If the working time is extended to 12 hours, the limit value must be lowered to 0.67,10^4 J/m² according to formula (6).

An evaluation of the natural UV radiation by the sun is not planned for the evaluation in the context of the long working hours.

8.8. Exposure to electromagnetic fields

The exposure limit values of the VEMF (*Ordinance on Electromagnetic Fields*) are acute values with a measuring period of 6 min. These values must not be exceeded regardless of the working time. This is due to the fact that the basis for the limit value derivation are direct effects (occurrence of nerve and muscle excitations, phosphenes, tissue warming). However, it is largely certain that EMF can also have chronic effects. For precautionary reasons, it is recommended that, as with optical radiation, a proportional reduction in the limit values be

made if the working time exceeds 8 hours.

8.9. Consequences for investigations pursuant to the VGÜ

It is known that if the TLV is exceeded by 50% or the TRC value by 1/20, suitability tests and follow-up tests are to be carried out in accordance with the VGÜ. If the working time exceeds 8 hours, the corresponding adjusted limit values shall be used. This changes the trigger condition for occupational health examinations and such examinations must be performed at lower workplace concentrations. In accordance with the ZAI decree, however, it is essential to consider whether more than half of the regular working time is performed in the form of shifts lasting a maximum of 8 hours. If this is the case, then the TLV and TRC value interpreted for 8 hrs is used in the examination of the examination requirement in accordance with §49 paragraph 1 of the ASchG.

8.10. Consequences for employees covered by the night shift heavy labour law

Although the ZAI regulation does not address the problem of the combination of night work and heavy labour, it follows from the basic concept that the heavy labour factors mentioned in the NSchG *(Night Shift Heavy Labour Act)* must also be subject to adjustment in the case of extended working hours. For noise and vibrations, the above concept should be applied. The same applies to carcinogenic working substances or substances whose exposure can lead to an occupational disease. In the latter case, the TLV or TRC value reduced by the reduction factor must be used as the limit value before checking whether the effect exceeds 75% of this value.

When combining heavy physical work and heat, it is necessary to consider that both the continuous performance limit for heavy physical work and the reference values for stressful heat during extended working hours must be reduced.

Stressful heat conditions are present if, during at least 50% of the working hours the average outside temperature leads to conditions which are equivalent to (or worse than) 30°C and 50% relative humidity at an air speed of 0.1 m/s (night shift heavy labour law VII-2-2). According to the regulation (BGBl. No. 53/1993) it was determined that such a climatic condition exists,

- if an effective temperature (ET) of 25.3°C is exceeded with predominantly convective heat exchange
- if a globe temperature of 25.3 °C is exceeded with simultaneous convective heat exchange and simultaneous radiant heat load of more than 50 W/m²
- if the predominant heat radiation load from 348 W/m² heat flux density is 30% of the total working time, from 580 W/m² 20% and from 870 W/m² 10%.

The determination of the heat load is carried out according to ÖNORM A 8070 (Annex to the Regulation BGBl. No. 53/1993).

Although no explicit reference is made to an 8-hour daily working time, this time reference is evident due to the physiological basis of the dissipation of stressful heat. If the daily working hours are extended, the specified shares can no longer be accepted unchanged. In addition,

the above-mentioned regulation and the NSchG do not address the activity level (i.e. work-related heat production), which accounts for a significant proportion of the thermal load.

In order to determine the necessary reduction in climatic stress and/or increase in break times, the figures in Hettinger (1979) and ACGIH (2001) can be used, whereby the work energy conversions applied here must be increased by the factor by which the working time is extended (e.g. if the working time is extended to 12 hours, the factor is 1.5; a work energy conversion of 800 kJ/h is therefore estimated at 1200 kJ/h to determine the reasonable climatic stress or break times). However, this procedure is only applicable if the extension of working time is carried out without changing working conditions and job requirements.

Activities in which the air temperature is 15°C or less for at least one hour are referred to as cold work. According to DIN 33404, Part 5, a distinction is made between five cold zones: I, cool range: 15 to 10°C; II, slightly cold range: 10 to -5°C; III, cold range: -5 to -18°C; IV, very cold range: -18 to -30°C; V, cryogenic range: below -30°C.

Stressful cold in the sense of the NSchG is present if the temperature of the working chamber falls below -21°C or if a constant change between such conditions and normal temperature is required.

In the short term, the reduced blood circulation in the skin and extremities during cold work reduces mobility, sensitivity and dexterity and causes a sensation of cold. Attention and responsiveness decrease, which increases the risk of accidents. In the long term, this can lead to diseases of the vascular system, the urogenital tract, the musculoskeletal system and to delays in the recovery from illnesses with other causes.

An extension of the working time beyond 8 hours can only take place if the break times are increased disproportionately. The rule of thumb is a factor of 1.5 (that is, if the working time is increased by 50%, the break times must be increased by 75%). When working in very cold and cryogenic areas, the daily working time may not be extended beyond 8 hours even if the break times are extended, unless the total working time in very cold and cryogenic areas does not change as a result.

9. Framework conditions for design

9.1. Autonomy (M. Kundi)

Adequate room for manoeuvre and decision-making on the part of employees plays a significant role in reducing work-related stress. Furthermore, employee involvement is of utmost importance when introducing and implementing changes in working hours. This not only increases the acceptance of new working time regulations, but also reduces the restrictive consequences of the workload due to the activity as well as a special situation and longer duration of working time.

The continuous involvement of employees in the organisation of working hours is particularly effective in reducing the burden. An individualised shift plan largely determined by the employees themselves is possible, especially in smaller shift groups. As there are working and leisure times with varying degrees of attractiveness, such flexible systems must be ac-

companied by a bonus or penalty system or other compensatory measures in order to avoid disadvantages.

9.2. Individual and social framework conditions (Kundi M.)

Although the individual situation of employees can only be addressed to a limited extent in the context of an occupational medical assessment of a working time regime, some general guidelines are nevertheless to be taken into account:

- **Getting to work:** When assessing working time, the additional time tied to work should also be taken into account. This includes in particular the commuting distance to work. If a significant part of the workforce has a long journey to work, an extension of the working shifts can lead to a reduction in the time tied to work. On the other hand, the risk of accidents on the way to work must be taken into account. On the one hand, fatigue and tiredness are relevant, but also the general traffic volume during the journey times.

- **Commuters:** These considerations apply particularly to people who commute on a weekly basis. Condensation of the working week can have both favourable and unfavourable effects.

- **Secondary employment:** Although people who work a sideline benefit from a reduction in the number of working shifts, the sideline represents an additional burden which, together with the increased stresses caused by the extended shift duration, can exceed the limits of compensatory capacity.

- Family situation: The importance of the hours of the day varies according to family situation and care responsibilities. Depending on the age of the children in the family, different times of day are significant for family responsibilities. For a younger team, it is important to keep the number of consecutive shifts small, while for older workers who no longer have school-age children, longer free shift blocks are less troublesome.

- **Living situation:** When working night shifts, it is necessary to sleep during the day. Workers must have a room in their dwelling where they can sleep in a pleasant climate and where they are adequately protected from noise and light.

- **Health status:** Working hours exceeding 8 hours represent a special strain and are particularly for persons with chronic illnesses, which require a permanent medication, linked to careful consultation and adjustment of the medication in accordance with the changed working hours.

9.3. Operational health protection measures for longer working hours

It follows from the above that health protection and health promotion measures in the workplace become even more important with longer working hours. On the basis of the stress-strain concept, it is to be expected that longer working hours, especially 12-hour shifts, cannot be coped with equally well by all employees. Employee surveys are recommended as an accompanying measure for the early identification of problem cases, whereby, for example, a survey of the workability index (WAI) is a suitable instrument.

These employees* should be given intensive advice during their check-up for night work in accordance with §51 ASchG. The further procedures in the company in these cases are to be regulated in a works agreement.

Food intake is also particularly important for longer working hours. Particular attention should be paid to the general rules governing shift work, e.g. the possibility of having a hot meal during the night shift.

Furthermore, it should be noted that a sufficient number of employees are employed in companies or parts of companies with longer working hours in order to avoid a further extension of working hours through additional overtime in the event of absences (due to illness or vacation).

9.4. Selection of personal protective equipment PPE:

Long standing activities:	heel cushioning, comfortable, “breathable”, note: drying times!
Long sitting activity:	ergonomic equipment, upholstery fabric (swivel chair) and clothing VDU workstation, etc.!
Hand protection:	Gloves adapted primarily to the activity, long exposure possibilities usually not always given, observe change
Skin protection:	observe “wet work” max. < 2 hrs with water, instruction on use
Safety goggles:	Wearing comfort, opt. compensation for shortsightedness and presbyopia;
Body protection/protective clothing:	weight, breathable,
Ear protection:	reference to exposure, wearing comfort

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