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CRITERIA FOR THE ASSESSMENT OF ERGONOMIC MEASURES IN THE COST-BENEFIT ANALYSIS

BENEFITS OF ERGONOMICS

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Criteria for the Assessment of Ergonomic Measures in the Cost-Benefit Analysis

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1 INTRODUCTION

Musculoskeletal disorders are the most common cause of work incapacity days due to sickness in Germany, Austria and Switzerland [1,2,3 quot. 4].
Especially older people are affected [5]. As a result of demographic change and the associated ageing workforce, a sustainable workplace design should increasingly take preventive, ergonomic design measures into account.

Even though the general positive effects resulting from ergonomic workplace design measures are rarely doubted, the best approach to convince decision-makers at companies of the benefit of an ergonomic design measure is to demonstrate the economic benefit that the company can derive from it.

As results from numerous published studies, however, this benefit can manifest itself in very different forms.
In this context, the various intentions of companies and employees will always be oriented towards the following goals:

- Maintenance of good health
- Prestige
- Economic interest

These are only rarely opposing goals. A number of studies have shown that healthy and content employees are also more effective.

This review was commissioned by **Ergoswiss AG** as an extension to the guidebook "Ergonomic Workplace Design: Musculoskeletal relief principles deriving from the exercise, sports and human factor sciences".
The goal of this review is to provide a summary of the results of published studies that investigated the advantages and the benefits of ergonomic design measures.
Aside from the general analysis of ergonomic design measures aimed at relieving the musculoskeletal system, this review focusses on height-adjustable work desks.

2 ECONOMIC EFFECTS OF ERGONOMIC WORK-PLACE DESIGN MEASURES

The two most frequently used calculation models for assessing the economic benefit of ergonomic measures are the cost-benefit ratio and the period of amortisation (cf. [6]).
When applying these calculations, the challenge consists in how to determine the individual values of a company.
In this chapter, the direct benefits of ergonomic measures and the indirect costs resulting from a lack of health-promoting measures are listed. Based on this, the value or respectively the benefit provided by a health-promoting measure can be determined

Cost-benefit ratio

This method is used to put the costs incurred for the implementation of the ergonomic solution in relation to the benefit achieved by this measure.

$$\frac{\textit{Cost of implementation}}{\textit{Value of the benefit}} = \textit{Cost-benefit ratio}$$

Period of amortisation

This method is applied to determine the time required for the amortisation of the investment made.
For this, the costs and the benefits of ergonomic measures must be calculated.

$$\frac{\textit{Cost of investment}}{\textit{Benefit per year}} = \textit{Amortisation period (in years)}$$

These methods can be used both retrospectively (looking back) and prospectively (looking into the future).
What makes a prospective calculation more difficult, however, is the fact that the positive effect to be expected (i.e. the benefit) must be estimated.

2.1 BENEFITS OF ERGONOMIC MEASURES

Financial / economic effects

The positive cost-benefit ratio for health-promoting measures of companies is undisputed in the scientific literature [7].
The results of a number of studies have demonstrated the positive economic effects associated with health improvements. These economic effects result from an increase in productivity and the reduction of ancillary costs that are incurred when staff is sick. In their calculations, independent US-American studies have assumed a cost-benefit ratio ranging from 1:2.3 to 1:5.9. This means that for every dollar spent, 2.3–5.9 dollars can be saved due to reduced sickness-related costs [7].

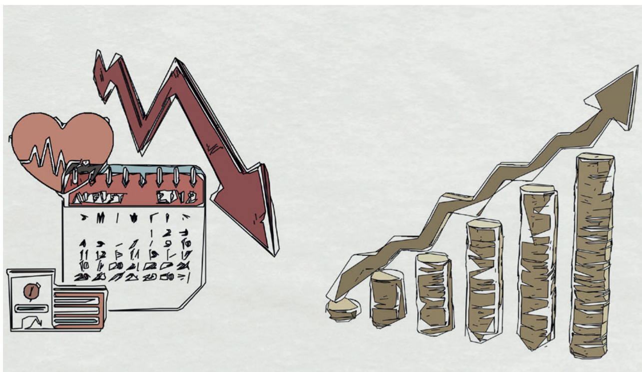

Figure 1 Investment to reduce sick days pays.

When looking at these calculations of the cost-benefit ratio, however, it must be considered that most of the values were derived from US-American studies. The applicable legal provisions and employment conditions in the US differ from those in other countries to some extent. For this reason, the value of these effects

cannot be transferred directly to European countries.
A comprehensive review summarised the results derived from 250 case studies that investigated the benefit of investment made in ergonomic measures [8]. Comparable parameters were extracted and represented. Even though the authors stress that the results should be interpreted with caution they show a consistent trend (cf. Table 1).

Notes for reading the table using "Productivity" as an example: ***61*** *of the 250 studies investigated the* ***productivity.*** *On* ***average,*** *the increase amounted to* ***25%****. The value of the study whose result corresponded to the mean value was* ***20%*** *(=* ***median****). In 95% of the studies, a productivity improvement of* ***20-30%*** *was achieved (calculated* ***confidence interval****. Overall, the* ***range of results*** *of the studies varied from very minor negative changes of* ***0.2%*** *to very significant changes of* ***80%****.*

Parameters for determining the effectiveness	Number of studies	Average	Median	95% confidence interval	Range of results
Productivity	61	25% ↑	20% ↑	20 - 30%	-0,2 - 80% ↑
Incidence* (number of new cases of sickness per year)	53	65% ↓	67% ↓	57 - 73%	9 - 100% ↓
Number of days of work lost*	78	75% ↓	80% ↓	70 - 80%	3 - 100% ↓
Number of days of restricted work	30	53% ↓	58% ↓	42 - 64%	5 - 100% ↓
Number of work-related disorders of the musculoskeletal system	90	59% ↓	56% ↓	54 - 64%	8 - 100% ↓
Personnel costs	6	43% ↓	32% ↓	17 - 69%	10 - 85% ↓
Rejects/ errors	8	67% ↓	75% ↓	59 - 85%	8 - 100% ↓
Days of absence due to sickness	11	58% ↓	60% ↓	43 - 63%	14 - 98% ↓
Period of amortisation of the investment**	36	0,7 years	0,4 years	0,4 - 1 year	0,03 - 4,4 years
Cost-benefit ratio	5	1:18,7	1:6	1:7,6 - 1:45	1:2,5 - 1

* Due to work-related musculoskeletal disorders
** The calculations include claims for damages of employees according to US-American law.

Table 1 Summary results table from 250 case studies (adapted from [2])

Typical benefits mentioned in the review include the reduction of work-related musculoskeletal disorders or the incidence rate of these. Another benefit mentioned referred to the reduction of days of absence due to sickness or of days of restricted work, i.e. workdays during that employees were not fully fit to work. These restricted workdays can also have a negative impact on the number of defective products in production, among others (increasing rejects rate).

→ Even though no accurate calculation models are available, extensive evidence of the positive cost-benefit effect achieved by investment in health-promoting mea sures can be found in the literature.

2.2 RISKS ASSOCIATED WITH A LACK OF ERGONOMIC MEASURES

Risk analyses that assess days of absence due to sickness typically include all costs directly associated with the absence of an employee. Depending on how much detail is included in these calculation models, however, a number of additional financial risk factors exist. The share of these indirect costs can be significantly higher. Due to their speculative nature, however, they might not be considered in cost-benefit analyses. Nevertheless, costs and benefits are not weighed off against each other correctly if we fail to consider these criteria in the calculation.
As is the case with an iceberg (see Figure 2), the greater part of the costs will be found underneath the surface [9]. In the following, some of these indirect risk factors found in the literature are listed and explained:

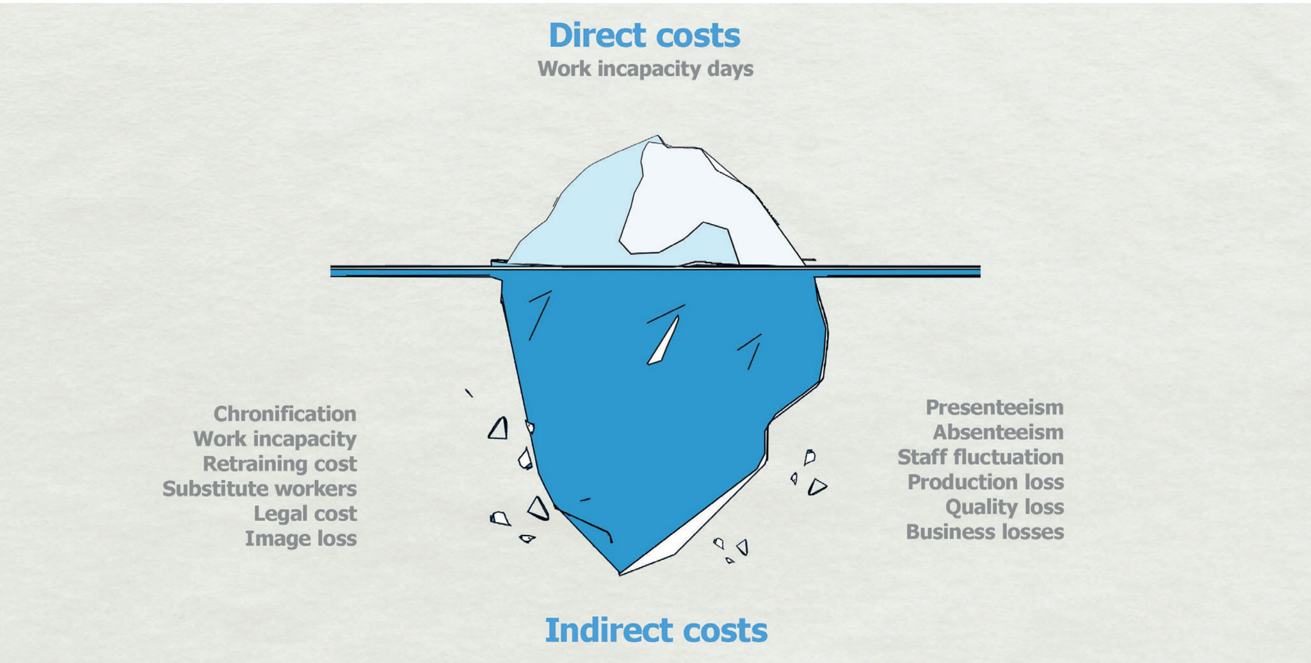

Figure 2 Many cost-benefit analyses neglect the greater share of the indirect costs.

Absenteeism

Days of absence due to illness result in increased costs as the salary of the sick employee as well as temporary substitutes or overtime to compensate for the sick employee's work must be paid [9]. Musculoskeletal disorders are considered the most common type of sickness causing days of absence (AB days) in Germany, Austria and Switzerland [1,2,3 quot. 4].
In particular, back pain that can be caused by constrained body postures at the workplace account for one of the most frequent physical complaints in the population [10, 11].

Presenteeism

Employees who come to work even though they are sick are less effective in terms of productivity and quality. It is estimated that the financial losses due to presenteeism are higher than the losses due to days of absence [12, 13]. In addition, the lower performance and satisfaction of sick employees can affect their colleagues and have a negative effect on the work motivation of these [9].

Production losses

Depending on the organisation of a company, increased absence rates due to sickness can lead to production losses. This can be explained by a lower number of personnel or a lack of experience of new employees who must replace the colleagues who are absent due to sickness. As a consequence, the production rate decreases while the error rate increases [9].
In addition, unergonomic workplaces may result in early fatigue and loss of concentration, which may have an impact on product quality. Additional costs may be incurred as a result of return costs or even the image loss of the company [14].

Chronification of sickness

Musculoskeletal disorders resulting from constant constrained body postures can manifest themselves over time and become chronic [15]. These slowly developing disorders are typically associated with a longer healing process compared to sicknesses that develop suddenly. For example, it is estimated that the number of sick days due to occupational diseases not caused by an accident are 1.6 to 2.2 times higher [16]. Later on, additional costs may be incurred in connection with retraining and rehabilitation measures [9].

Staff fluctuation

Poor work conditions result in higher fluctuation. The process for recruiting and employing new staff is both time-consuming and costly. In addition, new employees must initially be trained and are therefore unable to replace the productivity of experienced employees directly [9, 17].

→ Cost-benefit calculations that only consider the direct costs are incomplete as they only look at the "tip of the iceberg".

3 ERGONOMIC POTENTIALS OF HEIGHT-ADJUSTABLE WORK DESKS

Various indicators for assessing the effectiveness of ergonomic measures can be found in the literature. According to these, height-adjustable work desks account for approx. 40%, ranging between lifting aids that completely absorb the strain caused by heavy loads (approx. 70%) and job rotation (approx. 15%) [8, 18].
In the following section, the major potentials associated with height-adjustable work desks are listed and supported by indicators and results taken from the literature.

3.1 DIRECT ECONOMIC POTENTIALS

Increase productivity / product quality
Several studies suggest that the productivity or the quality of the work can be increased by the introduction of sitting-standing workstations [19–21]. Aside from the office environment, numerous case studies in production have shown that the introduction of a height-adjustable work desk resulted in the same positive effect [8, 21]. No negative effects on the productivity of the workforce as a result of the introduction of sitting-standing workstations were found [22–24].

Reduce days of work incapacity
Risk factors for musculoskeletal disorders are considered to include excessive repetitions, uncomfortable and constrained body postures as well as lifting heavy loads [27]. Height-adjustable workstations can be used to avoid constrained body postures. Examples from production and office workplaces have demonstrated that height-adjustable worktables could reduce the number of sick notes due to musculoskeletal disorders by 42-50% [25, 26].
Study results even suggest that the introduction of sitting-standing workstations may significantly reduce pain in office employees suffering from chronic back pain [27].

→ Numerous studies have confirmed the quote by H.W. Hendricks "Good Ergonomics is Good Economics" time and again [28]

3.2 INDIRECT ECONOMIC POTENTIALS

Numerous positive effects are associated with an ergonomic optimisation through height-adjustable work desks, some of which are interrelated and have an effect on both the employee and the employer. Aside from the adaptation to the individual body height of a person, many height-adjustable desks also permit alternating work in a sitting and in a standing position (sitting-standing workstation).

Figure 3 Ergonomics can improve productivity and product quality

Reduce sitting times

Many recent studies have shown that the time we sit during a day has an effect on our health. This includes musculoskeletal disorders, cardiovascular diseases or an increased risk of type 2 diabetes or cancer [29, 30]. These findings also contributed to the creation of the slogan "sitting is the new smoking", which in the meantime has been used as a book title [31], in health guides or as advertising slogan for wellness programs of health insurances

The introduction of sitting-standing workstations can reduce sitting times and promotes body posture variation [32, 33]. Figure 4 shows clinical pictures that may be aggravated by extended sitting periods.

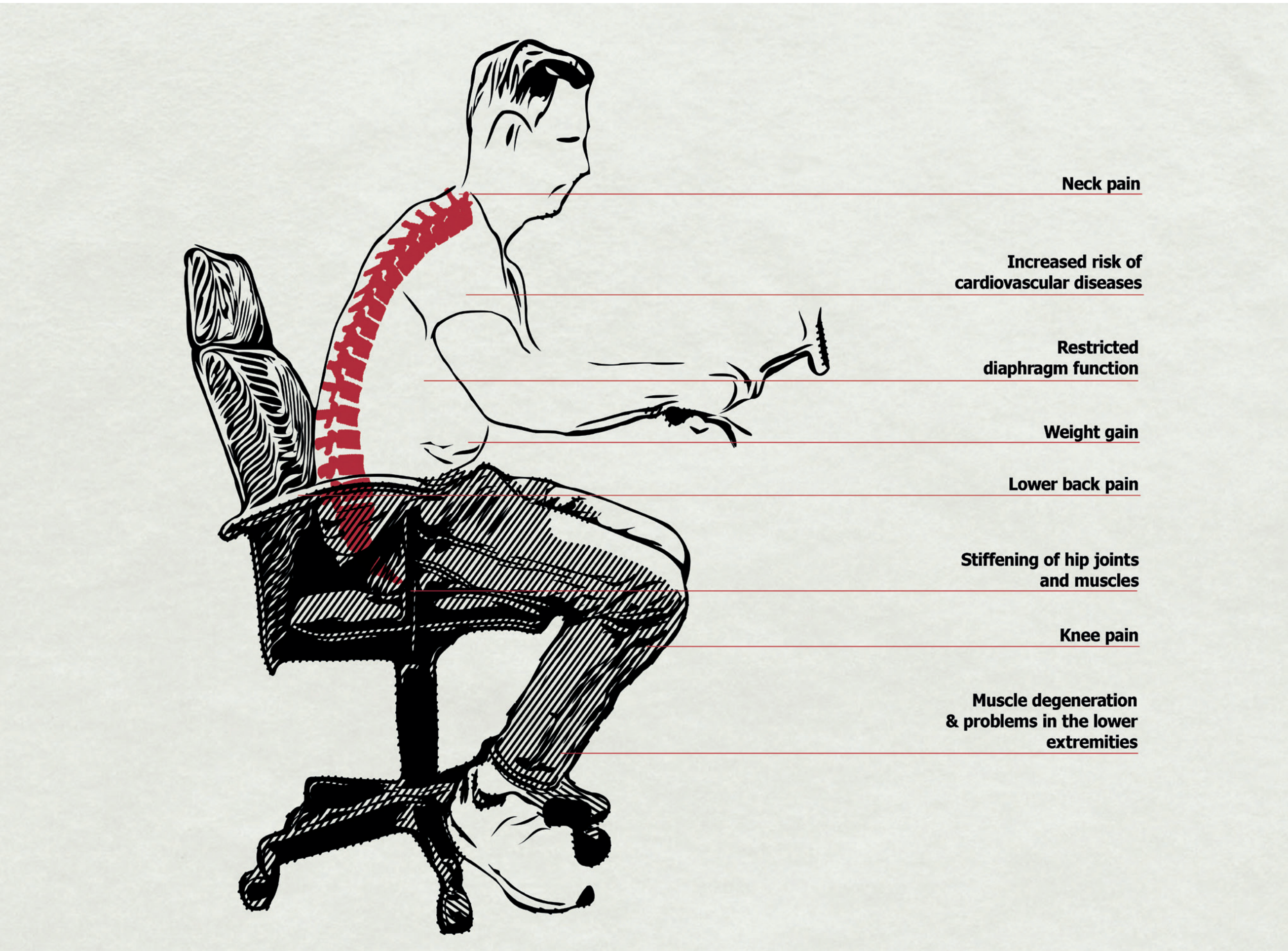

Figure 4 Extended sitting periods may be a factor in diverse clinical pictures (cf. [31])

Prevent postural defects

Height-adjustable work desks can be adjusted to the individual body height of the employee both in sitting and standing position, thus avoiding constrained body postures. The thus assumed upright body posture is characterised by economy, favourable energy consumption and efficiency [34].
Even though, according to recent findings, there is no single optimal sitting position [35], an inclined body posture is considered to be connected with an increased flexion of the lumbar spine and a risk factor for back pain [36].
A sitting-standing workstation can reduce constrained as well as static postural patterns [23, 33].

Increase calorie consumption

In view of the current interest in fitness and health, as can be deducted from prognoses regarding the popularity of fitness trackers or apps [46, 47], it may be particularly interesting for employees working in offices that a standing workstation burns more calories than a sitting workstation [48–50]. Several studies have shown that calorie consumption could be increased by 5-8% compared with a sitting workplace [48, 49].

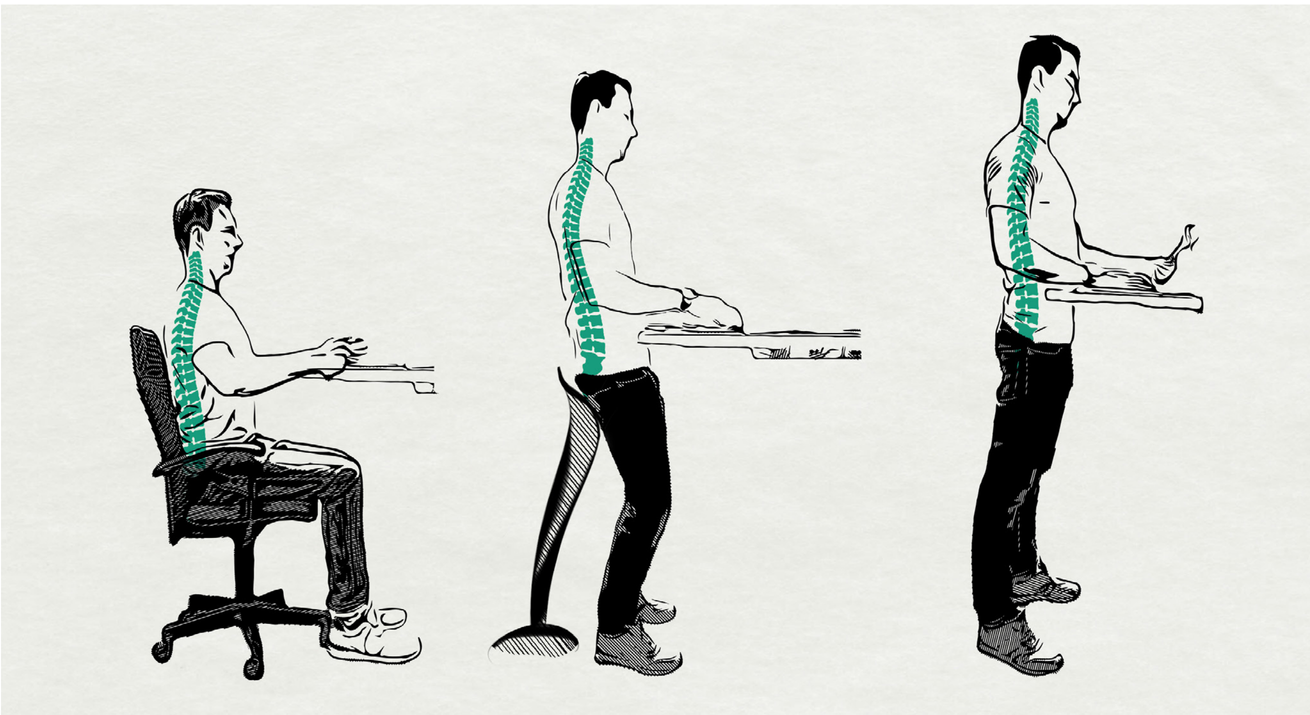

Figure 5 Height-adjustable work desks permit flexible work, adapted to the individual body height

Avoid discomfort

An ergonomic workplace design that promotes alternating body postures (e.g. sitting-standing workstations) reduces muscular discomfort. In several studies, this could be demonstrated for both office and industrial workplaces [24, 26, 37–39]. Consequently, a possibly low muscular discomfort can be rated as an influencing factor for the subjective well-being of the staff.

Figure 6 Ergonomic workplace design decreases muscular discomfort and increases subjective well-being

Reduce muscle strain and tension

An unfavourable worktable height can have a negative effect on the musculoskeletal system. For example, a workplace that is adjusted too low provokes a slight forwards inclination of the trunk and the neck, increasing muscle tension in these regions [40]. If we maintain these postures over extended periods, this can result in tension and stiffening of the muscles in the back, shoulder and neck region.
In the long run, this can lead to severe muscle disorders or tension headache [41].

An ergonomic workplace design can reduce muscle tension in the neck, shoulder and back region. In several studies, this could be demonstrated for office workplaces [42, 43], at school [44] and in production [45]..

Prevent fatigue

Fatigue is associated with reduced concentration and diligence, thus representing a risk factor for errors and accidents [51, 52]. As results from laboratory and field studies, the use of height-adjustable desks that permit working both in a standing and a sitting position, helps prevent the feeling of tiredness at office workplaces [20, 53].

Figure 7 Unlike a purely sitting workplace, a sitting-standing workstation promotes activity and helps prevent the feeling of tiredness

Increase staff satisfaction

Staff satisfaction is very important as it can affect motivation and performance [54]. This effect was demonstrated in connection with the introduction of height-adjustable work desks in an office [55] and in production [56]. In an illustrative example from production, an ergonomic optimisation of the workplace was linked with a 41% increase in satisfaction [56].

Enhance attractiveness of the company

As companies increasingly compete for qualified specialist staff – in the so-called "war for talent" – the attractiveness of a company is a decisive factor for recruiting and retaining staff [57]. Experts [58, 59] and companies [57] believe that professional corporate health promotion, including an ergonomic workplace design, among others, contributes to an increased attractiveness of the company.

Figure 8 When competing for qualified specialist staff, corporate health promotion may be a decisive factor.

4 SUMMARY

Extensive evidence can be found in the literature demonstrating the diverse benefits that can be achieved through the implementation of ergonomic measures. However, it is often difficult to incorporate these criteria in cost-benefit analyses.

Even though the research is unable to provide ready-to-use calculation models, it is not surprising that numerous studies have demonstrated that healthy employees are more content and effective.

To ensure the promotion of health of the staff and to make arguments for investments in ergonomic workplace design measures easier, the goal of this review is to help identify relevant criteria for the company that can be used to demonstrate the benefits of ergonomic investment.

The more holistic the approach we follow when considering the risks of a lack of health-promoting measures, the sooner investment in this area will pay.
The benefits of corporate health promotion and an ergonomic workplace can also be subdivided into benefits for the employee and for the employer (refer to Table 2).

Employer	**Arbeitnehmer**
Ensuring the performance of all staff	Fewer visits to the doctor
Increased motivation by strengthening the identification with the company	Improvement of the health-related conditions at the company
Cost reduction resulting from reduced sickness-related and production losses	Reduced stress
Increase in productivity and quality	Improved quality of life
Enhancement of the company’s image	Preservation / increase of own performance
Strengthening of competitiveness	Increased work satisfaction and better work climate
More resilient employees even in times of additional stress due to order volume fluctuations	Co-design of the workplace and the work process
Flexible workstations for employees of different body heights	Calorie consumption

Table 2 Benefits of corporate health promotion for employers and employees

5 LIMITATIONS

Even though an indisputable positive effect of the cost-benefit ratio can be derived from the literature, there are limits to providing a generalised statement due to a lack of comparability of the different studies and their design. In addition, studies from the USA always also include damage compensation costs in the cost-benefit calculation. Due to different legal systems, these cannot be transferred directly to European countries.

Studies not always distinguish between health programs aimed purely at ergonomic aspects and those that also consider other health aspects. Accordingly, it is not always possible to differentiate between the effects of measures aimed purely at relieving the strain on the musculoskeletal system and other health-promoting measures, including the prevention of diabetes or cancer, for example.

Moreover, it must be considered that there might be a distorting effect in the existing data due to a general preference to publish studies with positive or significant results ("publication bias"). This means that generally there is a trend to publish more studies that demonstrate the positive effect of a measure instead of studies that fail to demonstrate any effect.

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