

Occupational Health: The Global Evidence and Value





Jonas Steel

MSc, Leuven Institute for Healthcare Policy, Faculty of Medicine, KULeuven, Belgium

Jonas.steel@kuleuven.be

Tel. +32 16 37 30 79



Jeroen Luyten

PhD, Leuven Institute for Healthcare Policy, Faculty of Medicine, KU Leuven, Belgium

Department of Health Policy, London School of Economics and Political Science, UK

Jeroen.luyten@kuleuven.be

Tel. +32 16 37 46 80



Lode Godderis

MD, PhD, Environment and Health, Department of Public health and Primary Care, KU Leuven, Belgium

IDEWE, External Service for Prevention and Protection at Work, Belgium

Lode.godderis@kuleuven.be

Tel. +32 16 37 32 91

“IOSH welcomes this comprehensive view of OH relevant research. While recognising that there is still more research to be done for this important subject, it provides good evidence that well-designed OH programmes bring considerable benefits to workers, their organisations, and the societies they live in.”

Vanessa Harwood-Whitcher
Director of Professional Services Institution of Occupational Safety and Health
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Executive summary

Effective occupational health measures result in the absence of health impairment (although this consequently remain invisible unless properly monitored). However, in general, existing economic evaluations sketch a mostly bright picture of the benefits of investing in occupational health.

Most work-related diseases are multifactorial in origin and appear after a relatively long latency period between exposure and health effects. Despite the difficulties and the challenges in the economic evaluation of occupational health interventions, both literature and case studies provide evidence of the global rationale for investing in occupational health for enterprises.

We first discuss the value of Occupational Health (OH) from a global perspective. We apply a broad meaning to the word “value”, including financial aspects, legal, moral, and other less tangible effects (such as effects on the corporate image). Next, we synthesise the global evidence on OH, combining indications from the scientific literature with case studies and illustrate the following key messages:

Key message 1: The benefits of occupational health can accrue to all involved stakeholders – employees, enterprises, healthcare payers, and society – most importantly through gain in employee health, reduction in absenteeism, presenteeism, and healthcare costs, and improvement in reputation.

Key message 2: There is a strong moral rationale for investing in OH. Apart from not harming workers and the potential health improvements, OH programmes have the potential to reduce unfair inequality and support equal access to healthcare, to diminish the health gap between high-income and low-income countries, and to protect vulnerable groups.

Key message 3: The value of OH interventions is strongly influenced by a country's workers' compensation and social security system. They can give rise to additional (avoidable) costs, and greatly influence the distribution of costs and effects across stakeholders. Meeting standards and complying with legislation can have important financial and non-financial benefits.

Key message 4: Despite limitations on the quantity and quality of available research, the overall health-related impact and return-on-investment of well designed OH programmes is positive for a wide variety of interventions in different countries. While more research is needed in many areas, key factors of successful interventions are listed wherever the evidence allows for it.

Key message 5: The workplace health agenda can broaden its scope beyond traditional occupational medicine, and include workplace wellness, sustainability, and corporate social responsibility. Leading industries have already seized this opportunity by taking occupational health beyond minimum national legal requirements, and offering guidance to others to expand the value of occupational health to these dimensions in the future.



I. Introduction: a global view on occupational health

The global burden of occupational health (OH)

problems is substantial. Table 1 shows that 380,500 work-related accidents (in 2014) and over 2.7 million work-related diseases (in 2015) were fatal to employees worldwide.

A recent project^A estimated the economic burden for all fatal and non-fatal work-related injuries and illnesses at a loss of 3.9% of all work-years globally, equivalent to a cost of approximately € 2680 billion (or US \$ 2966 billion) for low-, middle-, and high-income countries (1, 2). This is roughly equivalent to 4% of the global Gross domestic product (GDP) worldwide, which is equivalent to the entire GDP of the United Kingdom (3).

A Realised by a cooperation of the International Labour Organization (ILO), the Finnish Ministry of Social Affairs and Health, the Finnish Institute of Occupational Health (FIOH), the Workplace Safety and Health (WSH) Institute in Singapore, the International Commission on Occupational Health (ICOH) and the European Agency for Safety and Health at Work (EU-OSHA).

Table 1 | Work-related Injuries and Diseases in the World

WHO Region	Economically active population (2014)	Fatal accidents estimate (2014)	Fatal work-related diseases (2015)
High-Income Areas	521 662 897	10 757 0,0021%	434 840 0,0834%
African Region	350 749 965	65 145 0,0186%	279 042 0,0796%
American Region	297 081 063	19 388 0,0065%	152 754 0,0514%
Eastern Mediterranean Region	195 451 073	21 113 0,0108%	152 375 0,0780%
European Region	227 406 974	14 159 0,0062%	223 253 0,0982%
Southeast Asia Region	824 496 607	124 404 0,0151%	807 705 0,0980%
Western Pacific Region	953 638 990	125 535 0,0132%	734 497 0,0770%
Total	3 370 487 570	380 500 0,0113%	2 784 465 0,0826%

Source: (4). Percentages are relative to the economically active population of the region (in 2014), region definitions according to the WHO (5), the list of high-income countries follows Hämäläinen (4). Note that the high-income areas are excluded from their corresponding WHO regions.

In **high-income countries**, improvements in occupational health and safety are seen as one of the ten biggest public health achievements in the 20th century (6, 7). Important decreases in fatal occupational injuries, improvements in mining safety, successful vaccination against hepatitis B, reductions in communicable diseases, and many more advances can be added to the OH community's tally (8). Continued vigilance is necessary however, since old problems thought to have disappeared can re-emerge once follow-up stops. They can also appear in other sectors, such as the reappearance of silicosis in American coal mines ((9) as cited by (10)) and South-African gold mines ((11) as cited by (12)).

The dynamic world economy also gives rise to the introduction of new products on a daily basis such as nanomaterials or e-waste (10, 13, 14). New(er) health problems related to the transition to the services sector (such as musculoskeletal and psychosocial problems) come to the fore. In addition, an ageing workforce and the corresponding demand for employees to stay at work longer and healthier (15) intensify the call for high quality occupational health interventions. These concerns were reflected in the priorities identified in the EU strategy 2007-2012 on health and safety at work (16) and were also expressed in the European Parliament resolution on the mid-term review of this strategy (17). The current EU Occupational Safety and Health (OSH) Strategic Framework 2014-2020 identifies three major health and safety at work challenges:

- to improve implementation of existing health and safety rules, in particular by enhancing the capacity of micro and small enterprises to put in place effective and efficient risk prevention strategies
- to improve the prevention of work-related diseases by tackling new and emerging risks without neglecting existing risks
- to take account of the ageing of the EU's workforce.

In **low- and middle-income countries**, occupational health is an even more emerging issue. Compared to high-income areas, fatal accidents (in 2014) are higher in all of the WHO regions, and fatal diseases (in 2015) are higher in the Southeast Asian and Western Pacific regions (4). However, because of low reporting, the actual figures remain an underestimation of the reality. Consequently, great progress must be made on the reduction of known recognized occupational and work related diseases by limiting exposure to both new and known health hazards - such as silicosis, asbestosis, lead toxicity or pesticide poisoning (18). Further, building and enforcing OH standards and legislation should be a priority concern (15). This holds not only for the formal economy, but also and even more for the many informally employed, where records or programmes to prevent injuries are much less available or even completely lacking (19, 20).

While these issues are challenging, they also emphasize the enormous potential of occupational health programmes: **the majority of these diseases, injuries and accidents are preventable** (21) at, mostly, limited costs. This makes OH of capital importance, not only for the health, safety, and well-being of the global working population, but also for enterprises and society as a whole (19). For employers, improving health at the workplace can result in reduced absences from work, can increase economic productivity and competitiveness of its staff, can reduce insurance

premiums or medical costs, and can yield a range of intangible gains such as improved company profiles and worker engagement (22). For society, occupational health investments can additionally lower healthcare costs, and indications exist of a direct relationship between national (and company) competitiveness and safety at work (23, 24). Despite this, there are still substantial gaps in occupational health coverage for employees (25). A study among ICOH member countries noted on average only 19% of the total employed population was covered, showing great variety between countries (3 - 97%) (26).

This report will provide a narrative synthesis of the identified scientific literature on global occupational health (methodological details and issues are described in the Appendix). The main focus (also in methodology) is on occupational health, but where relevant information on occupational safety and health promotion/employee well-being will be given. Managerial practices or corporate organisation fall beyond the primary scope of this document. In addition, taking a global perspective requires consideration of the diversity of cultural and legal settings, which may require tailoring occupational health programmes to maximise effectiveness. To ensure relevancy for / applicability to different contexts, this report will therefore go beyond the occupational health problems of high-income countries, and also look at the (scarce) evidence available in developing countries. Secondly, the evidence will be illustrated with case studies from a wide range of countries around the globe. Finally, this report will take a broad perspective on the value of occupational health and employee well-being, taking not only tangible or financial effects but also legal, moral, and other intangible effects into account (27), and employing a holistic view of employee health (28).

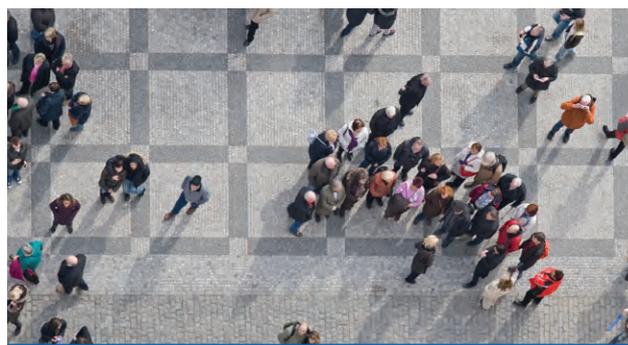


II. Value of occupational health for all stakeholders

Improving occupational health at work can have benefits for a whole range of stakeholders - workers, workers' families, healthcare systems, insurance companies, businesses and shareholders, customers, and even other companies (e.g. when it allows the firm to produce higher quality or more goods for other companies down the supply chain), since all of these parties avoid costs when work accidents or diseases are prevented (29).

This section provides an overview of the most important benefits of investing in occupational health by focusing on three main stakeholders: employees, employers, and society (incorporating the benefits for all of the above)^B. Some of these benefits are easily expressed in monetary terms (such as fines from legal violations, compensation of occupational diseases), while others

are less tangible (workers' health gains, corporate image) or are challenging to measure (increase in worker productivity). However, it should be kept in mind that lack of adequate measurement or monetization methods does not make the latter less important, nor their case pro investment less compelling.



A. Employee

Most of the world's population (58%) spend one-third of their adult life at work (30), making the workplace a compelling setting to protect and promote the health of employees during and beyond working life (31). In a broad sense, the **health gains from OH** interventions originate in the protection of workers and the prevention of accidents or injuries at work (and the pain and suffering this would have caused), the prevention or early detection of diseases, and the health benefits from return-to-work. They can also contain benefits of lifestyle changes from health promotion activities at work (e.g. smoking cessation programmes, reduced alcohol consumption by professional drivers). Finally,

health benefits do not relate only to physical health and safety (diseases, injuries, machine hazards, working at height, ergonomic hazards...), but also to mental and psychosocial health (stress, anxiety, aggression and violence, work-family conflicts, job satisfaction, social capital...) or interrelationships between both (15), which affect the general well-being of a worker^C.

In turn, these health gains can avert **income losses** for employees, such as wage losses during sickness absence, wage losses upon return to work, or reductions in medical treatment costs (20). The magnitude depends largely on the national healthcare and workers' compensation system. Regarding the first, in extremis, the worker may not receive an income during his entire absence without being compensated. This can, for instance, occur in cases of non-standard employment^D, a general lack of social / employer insurance, or gaps in the national legislation on occupational health (15, 20). Second, disability can also reduce income upon return to work, due to decreased productivity and wage discrimination (33-35). While efforts have been made to eliminate discrimination – the Equality Act 2010 (UK), The Accessibility for Manitobans Act (Canada), Americans with Disabilities Act of 1990 (USA), or Disability Discrimination Act 1992 (Australia) – prosecution and implementation of these laws remains challenging (20). Third, occupational health interventions affect the out-of-pocket payments of an employee: the portion of medical treatment costs that are not refunded (e.g. by health insurance). Unfortunately, it is mostly in low-income countries that out-of-pocket payments are highest (36). In addition, it is not unusual in developing countries to pay large informal (i.e. illegal “under-the-table”) payments to healthcare providers, which further drive up the

expenses for patients and their families (37). Because of these high healthcare costs, informal healthcare plays a large role in these countries. Consequently, occupational health interventions and healthcare provided are not only important for the workers but also strongly affect their relatives (20).

Finally, many burdens that fall upon the employee and his environment cannot be readily expressed in monetary terms, such as the strong emotions and mental impact that accompany accidents and disability, or the grief of relatives and friends in the case of fatalities (20). Once again, the fact that costs or effects are hard to express in terms of money does not diminish their importance (29).

However, it is also important to emphasize that work is an important part of people's lives that creates **value and meaning** (38, 39). Returning to work (RTW) after illness or injury can play an important role in treatment, recovery and rehabilitation, e.g. by leaving the passive “patient role” to active “worker role” (40). But also beyond return-to-work, research has indicated a strong evidence base for the positive effects of work on health, as well as for the negative effects of worklessness on physical and mental health and well-being (41).



C While this might seem counter-intuitive, it is both theoretically possible and empirically feasible to convert health gains in monetary terms, for instance through willingness-to-pay estimates for health states, or by placing a value upon a human life or (quality-adjusted) life year (32). This allows for direct comparisons of a programme's costs with its effects.

D “Work that does not conform to the traditional model of a permanent, full-time relationship between the worker and the enterprise at which the worker works” (20), such as part-time or self-employment, flexible work, or other forms of employment that reduce the claims an employee can make upon compensation.

B. Business

1. Financial factors

While the (direct) costs of implementing occupational health programmes are often visible to employers, the (indirect) costs of *not* implementing them are easily overlooked (20). A first component is the fact that occupational health programmes can improve **productivity**, principally because healthy employees have reduced sick leave (absenteeism) and increased productivity at work (presenteeism). Influenza vaccination for instance, can lead to less absenteeism by preventing flu episodes in employees and transmission among the workforce. Moreover, it can avoid productivity losses because of fewer flu-like symptoms, thereby leading to higher quantity (more) and quality (better) production.

Productivity impact is usually estimated through the calculation of lost working time from absenteeism and presenteeism, and converted into monetary values by multiplying with the (average) employee wage (42, 43). However, correctly measuring the true differences in productivity is a challenging endeavour (44)^E. Nevertheless, it has shown to be of crucial importance to the cost-effectiveness of occupational health in many

settings (47-50). It is even a frequent occurrence that the return on investment (ROI)^F due to the prevention of absenteeism alone (without taking health or other effects into account) is positive in many occupational health programmes (27, 49, 51, 52). For instance, one study calculated that absenteeism costs fall by about \$2.73 for every dollar spent on workplace disease prevention and health promotion programmes (49).^G

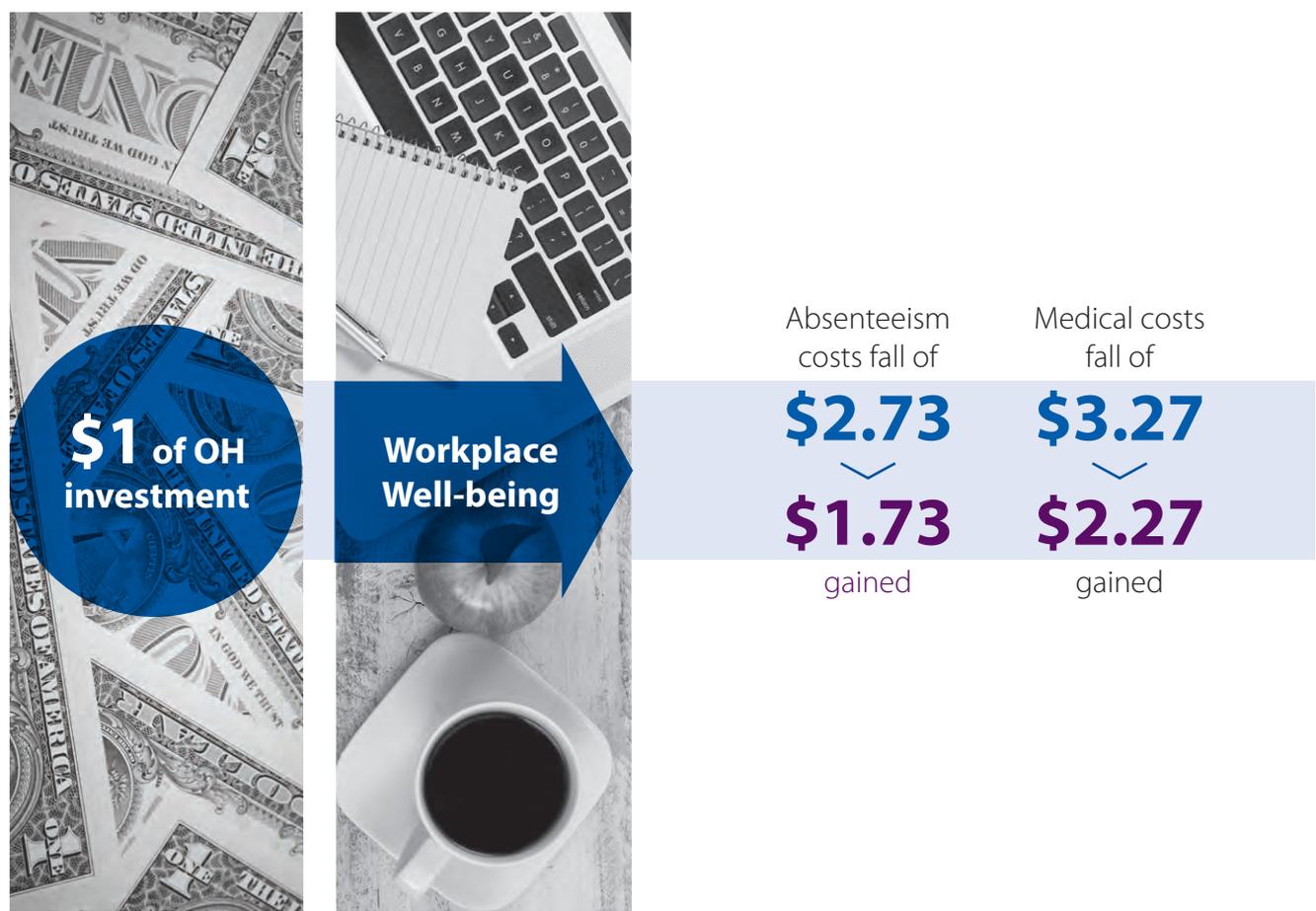
Reductions in healthcare or insurance costs are a second important financial factor at the company level. In general, improving the health of employees (or avoiding accidents) results in a reduction of health care consumption (e.g. by avoiding an employer-paid ambulance ride to the hospital (53)), and can reduce insurance premiums or replacement wages. When some of these are paid at least in part by the employer, such as payments of compensation benefits in the USA, investing in occupational health interventions can lead to substantial cost savings (49, 54). A study on workplace wellness programmes calculated that medical costs fall by about \$3.27 for every dollar spent (49). However, due to the large variety in health insurance and compensation systems, the ROI cannot be easily generalized. This topic will be discussed more extensively in the following sections.

^E More precise valuation methods of lost time take into account a range of knock-on effects, such as the fact that production losses can be compensated, for instance through temporary or permanent replacement workers in the friction cost approach (45). A second framework indicates losses can be larger when perfect substitutes are not available (i.e. difficulties in finding replacements), employees work in teams (e.g. when an absent surgeon causes a whole team to be out of work), or penalties occur when output targets are not met (46). Both effects have been shown to be of significant importance (47). Productivity increases can also come about through other mechanisms, such as increased worker engagement because of a better job climate, while it is even less evident how these should be measured or included.

^F The return on investment (ROI) can be defined as (benefits – costs) / costs

^G While these estimates should be interpreted with caution, as described in the Appendix. The studies included in the calculations focused on weight loss and fitness, smoking cessation, or multiple risk factors (including stress management, back care, nutrition, alcohol consumption, blood pressure, and preventive care) in addition to smoking and obesity (49).

Figure 1 | Two major elements of enterprise strongly influenced by workplace health promotion: Absenteeism and Medical Costs, in numbers (49)



Finally, a broad range of **other financial consequences** can be identified. Some of these are intervention-dependent, such as the costs of damages to material. Others depend on the regulatory context, such as fines for non-compliance to occupational health standards, workers' claims for injuries and diseases, management/HR time for handling them, or subsidies (and tax reductions) from authorities or insurance companies

(29). It is, however, not always easy to deduce what portion of expenses and costs can be attributed to the intervention, since mostly they are not (or in insufficient detail) accounted for (20). Interestingly, research has also demonstrated a connection between implementing an effective health and safety policy (all studied firms won a Corporate Health Achievement Award) and a higher stock market performance (23, 24).

Figure 2 | Examples of occupational health interventions and their financial outcomes/value

 <p>Silicosis prevention (114)</p>	<p>Cost per health year gained: \$105.89 - \$109.35</p>
 <p>Noise reduction (118)</p>	<p>Avoided OH costs and productivity gains: \$41,631.59</p> <p>Benefit to cost ratio = 13.23</p>
 <p>Manufacturing system mitigating injury risk (needle stick) (156)</p>	<p>Total cost savings: \$62,000 a year</p>
 <p>Training programme for 300 porters in Calcutta (179)</p>	<p>Costs savings: \$5,979</p>
 <p>Mental Health programme in Japan (209)</p>	<p>ROI: 0.27 - 16.82</p>
 <p>'Live for Life' programme at Johnson & Johnson (285)</p>	<p>Costs savings: \$565 per employee in 2009</p> <p>ROI: 1.88 - 3.92</p>
 <p>Workplace Wellness programmes (48)</p>	<p>Medical costs savings: \$1 spent = savings of approx. \$3.27</p> <p>Absenteeism costs savings: \$1 dollar spent = savings of approx. \$2.73</p>
 <p>Occupational safety training and schemes for health & safety in the German butchery sector (316)</p>	<p>Total costs reduction: €40 million in 6 years</p> <p>Savings: €4.81 for every euro invested</p>



The administrative cost of regulatory noncompliance

In radiation protection programmes, routine inspections of permit-holders are commonly used to ensure the quality of processes and can serve to improve outcomes. A study by Emery et al. (3) in Texas aimed to estimate the cost of regulatory noncompliance in this setting by looking at the costs of notices of violation (NOV), which are issued when items of non-compliance are noted on the inspections. They concluded that non-compliance led to additional costs for both the permit holder and the regulatory authority (and therefore in extension: society). Apart from intangible costs, such as damage to the organisation's reputation or worker morale, significant tangible costs were noted in the form of additional work to process and resolve the NOV. Data indicated that approximately US \$106,000 in (regulatory) personnel resources were needed to process and resolve the 6,800 NOVs issued in Texas during 1997 inspection activities (3).

2. Non-financial factors

Financial factors are not always the most appropriate, or the most accurate outcome to grasp the full benefit of implementing occupational health programmes. Financial results are influenced by many factors, making effects of occupational health hard to determine. Moreover, non-profit organisations may give more weight to quality or efficiency than to financial parameters; and excluding non-financial factors sets aside a broad range of other important benefits that are not easily expressed in monetary terms (29).

First, occupational health can influence a firm's **labour pool**: companies investing in occupational health can attract more (and more talented workers) and can lower recruitment and HR management costs (which might in turn affect the productivity of the firm) (29, 46). "Magnet hospitals" for instance, aim to create supportive professional nursing care environments, and have been able to recruit and retain highly qualified nurses in a competitive market (55, 56).

Another non-financial factor is the effect of (a lack of) investments in occupational health on **corporate (or government) image**. More than ever, the globalised consumer market has an eye for poor working conditions (12), transparency, disclosure, and accountability (28). The effects of occupational diseases and poor working conditions of employees on brand image and goodwill can be detrimental and hugely costly to counter. Illustrative of this is the large public attention on "tolerance for sweat shops" (12); treatment of migrant workers (12); textile factory accidents in Bangladesh (57); and the risks of overwork in Japan (58). However, effects of corporate image are not restricted to global firms. Often, small enterprises are highly embedded in the local social environment, and poor working conditions can have a very direct effect on sales, e.g. because customers live in the same village.



Brand image (Harvard Business Review)

Robert G. Eccles, a professor of management practice at Harvard Business School, underlined the importance of brand and corporate image in an article in the Harvard Business Review (59). Firms with strong positive reputations can attract better employees, have more loyal customers, and, because of the effect on the stock market's perceptions, they face lower costs of capital and higher market value. Eccles quotes Benjamin Franklin: "It takes many good deeds to build a good reputation, and only one bad one to lose it." Firms are vulnerable to reputation damage, but often handle crises and act only when things go awry.

Eccles' insights are directly applicable to the context of occupational health: numerous recent examples exist where firms were criticized in the media (e.g. by NGO's) about employees' wages, working conditions, and labour practices, etc. (59). Enterprises should instead manage their reputation and take action to improve actual behaviour: anticipating crises by timely investments in occupational health and maximising the effectiveness of reporting strategies.

C. Society

1. The societal perspective

Taking a **societal perspective** on occupational health programmes implies that all effects on worker ill-health are considered independent from the affected stakeholder. In the light of the previous sections, one could assume that the total societal benefits of occupational health could roughly be calculated as the "sum" of: the net gains in health and well-being, reductions in healthcare use and expenses, and avoidance of productivity losses. However, some additional elements must be considered (20).

First, **the value of OH goes beyond the stakeholders directly involved in the intervention**, because not all societal costs/benefits fall upon or stem from a specific stakeholder. For example, when an employee's illness or injury is prevented, society needs to pay neither the associated health care costs nor the disability benefits. As a consequence, the taxes/insurance premiums and reimbursements that would have been issued can now be spent for other purposes, or simply be deducted.

OH can also have other beneficial (macro-)economic effects that impact all citizens, such as raising the labour supply in the economy, or reducing the average labour cost (because of lower sickness absence and higher productivity per employee), an important determinant of the competitiveness of firms in the world market (45). Some of these effects are already captured by the productivity gains of individual firms, and they are best estimated on a national scale (45).

A societal analysis also brings in the **distribution** of the costs over different parties. While the total sum from a societal perspective might remain equal, there are numerous possibilities to shift and transfer costs from one party to another. Workers' compensation and accident claims (employee to employer), social or private insurance (risk pooling), or the market power of an enterprise (employer to consumers) are some examples (20). However, note that partial perspectives do not make the social case pro investment in OH less compelling. In the long run, cost shifting from private companies to social security systems will have an impact on the competitiveness of the private sector.

Finally, **not all stakeholder costs enter the societal view**. Some expenses lead to double-counting^H, while others are simply transfers from one party to another that negate each other in the societal "sum". For instance, worker claims are important costs to employers, but are not necessarily taken up in societal analyses because they are a cost to one party (employer) and a benefit to another (the employee).

2. Public health

Occupational health interventions can play a pivotal role in safeguarding public health, for instance in the case of outbreaks of infectious diseases or health-related disasters. This is especially relevant in low- and middle-

income countries, where the burden of these health problems often comes in addition to health issues faced in high-income countries. In Papua (Indonesia) for instance, the burden of both non-communicable and infectious disease comorbidities was demonstrated to be substantial among miners (60). We present several cases to illustrate the potential of occupational health programmes in this area.

It is inherent in the nature of communicable diseases that protecting one person reduces the risks of infection for others. In occupational health, an often-studied case is that of communicable diseases in healthcare personnel and their patients. For instance, a study in Eastern Ethiopia showed that 26.5% of healthcare workers had a sharp (e.g. needle) injury, and 36.1% were exposed to blood and body fluids. These exposures elevate the risk of acquiring blood-borne viral infections such as hepatitis B, hepatitis C, and HIV for the healthcare worker, but also for patients (61), who already face other health problems. Influenza vaccination of health care personnel follows the same logic. Vaccination reduces the risk of influenza infection of the health care workers, but at the same time prevents transmission to their patients (62). Similar arguments can be made for other diseases such as hepatitis, tuberculosis (63) or HIV (64).

In low- and middle-income countries, the fight against infectious diseases is not yet completed (60): the capacity to deal with outbreaks of (new) infectious diseases can be limited, and employees' access to (other) health care providers is not always evident. Occupational health can therefore play a crucial role in emergency response. The outbreak of Ebola in West-Africa in 2014 for instance, was followed by World Health Organisation recommendations to prevent infections at work, not only for healthcare, transport or burial

^H Double-counting is a technical problem encountered in applying a societal perspective in economic evaluations (32). For example: when an employee falls ill, the worker loses (part of) his income, and the employer loses part of its production output (because the employee did not produce anything in his absence). Both the lost employee income and the value of lost firm production can be used as an approximation of the lost value of production to society. However, if the analysis includes both, it would overestimate the value of lost production to society since they overlap, hence the term "double-counting".

team members (who are at increased risk and can play a key role in transmission) but also for employers and employees in general (65). In addition, a specific International Labour Convention (C155) also requires employers to protect employees against (occupational) health-risks, “so far as is reasonably practicable” (66), the importance of which has been recommended in Ebola as well as in future epidemic planning (67).

In turn, protecting or vaccinating employees (even when they are not at greater risk than others) to avoid a communicable disease can prevent infection for many other parties, such as the employee’s family, non-protected co-workers, and customers. This will also contribute to the other benefits mentioned in this report. For instance, it could avoid the temporary closure of an enterprise (and related productivity losses) by ensuring enough workers are available in the case of a public health emergency. Finally, it should be emphasized that occupational health does not only play a part in communicable diseases but can also be of significance in other disasters. The occupational health capacity that is already in place can assist where needed in the case of an emergency, and when little other medical assistance exists, as in some developing countries, it may be the primary access to healthcare. An example being the nuclear accident at the power plant of Tokyo Electric Power Company (TEPCO) in Fukushima, that occurred as a result of the earthquake and tsunami in March 2011 (68):

“The University of Occupational and Environmental Health (UOEH), Japan, dispatched physicians to a quake-proof building at the plant to provide first-aid services from mid-May, 2011, and took a strategic approach to protecting workers from health risks. Besides radiation protection, UOEH presented also recommendations on OH systems and preventive measures against heat stress to the Government and TEPCO. The Ministry of Health, Labour, and Welfare issued guidelines to TEPCO and contractors. TEPCO implemented a comprehensive programme against heat stress according to the guidelines and in cooperation

with UOEH. As a result, they successfully prevented severe heat illness during summer 2011.” (76)

3. Economic performance

At the national level, there seem to be good indications of a **link between economic performance and occupational health**. Reports show a negative correlation between the Global Competitiveness Index (GCI) and the number of annual occupational accidents of European countries (69, 70). In other words: the competitiveness of an economy seems to go hand-in-hand with its safety (71), although causal interpretations should be made with caution.

Key messages

- Investment in OH has benefits for all stakeholders
- Employees mainly gain from OH through improvement in well-being and health
- The main value of OH for companies lies in increased productivity (through reduced absenteeism and presenteeism); decreased compensation and health care expenses; and improved reputation
- Societal analysis incorporates the potential benefits for all stakeholders: health, production, healthcare use, and macro-economic effects, while disregarding transfer payments and avoiding double-counting

Figure 3 | Value of occupational health investments by category and interconnection between categories



III. Moral Case



Investment in occupational health has a strong moral underpinning. First, as implicitly assumed in the preceding sections, health improvements can be seen as imperative per se.¹

Many moral theories would agree that reducing the high worldwide burden of occupational accidents, illness, and injuries (1, 2) is imperative from an ethical point of view.¹ Some of these ethical arguments have already filtered through to the vision of the occupational community; in **the “Vision Zero”** view, for instance, that a world without fatal and serious accidents is possible. Creating a healthy workplace that does no harm to employees’ health is the ultimate goal (15, 21). Furthermore, this imperative applies to all employees and takes no account of borders; or as the WHO states: *“If it is considered wrong to expose workers to asbestos in an industrialized nation, then it should be wrong to do so in a developing nation”* (15).

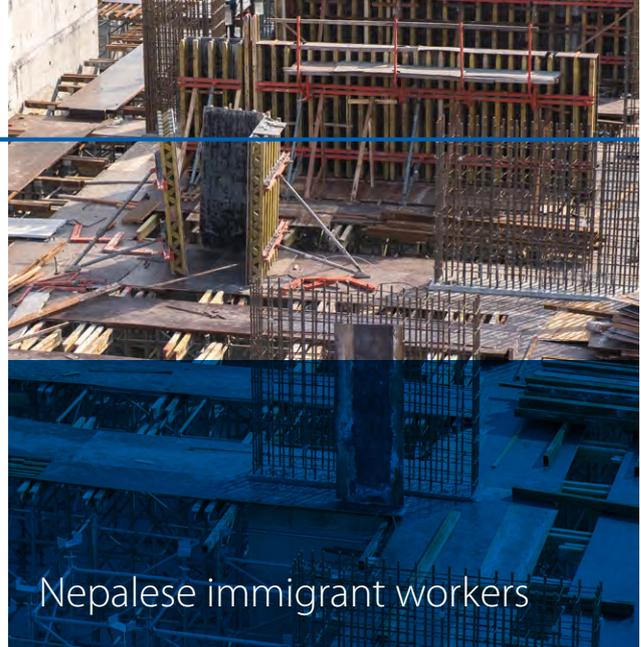
The concept of morality can be interpreted very differently depending on **firm size**. Larger organisations might be inclined to focus on larger themes (such as the environment, equality (gender or other), human rights,

¹ This is reflected in the fact that this view is implicitly taken up in many economic evaluations (the extra-welfarist framework) which try to maximise health gains in one way or another (32). Note that in this sense, the preceding (and following) sections should not be seen as descriptive or without value judgements, because they also reflect a normative/moral viewpoint: that it is worthwhile to invest in health.

^J From a utilitarian point of view for instance, the interests of all should be treated equally, and the morally right action is the action that produces the most good (72). Luck egalitarianism highlights that it is mainly the employer that decides on aspects of the production process, such that workplace health is not always a product of an employees’ own choice (73, 74). As a final example, several theories highlight the fact that people should not be seen as means (e.g. of production), but as ends in themselves. The moral case pro occupational health can thus be made on several grounds.

consumer protection, and also occupational health), not rarely because this helps them to retain employees or improves their reputation. Small and Medium Enterprises (SMEs) might be attracted to individual moral arguments in caring about occupational health (sympathy, solidarity, etc.) because the employer is often personally acquainted with many of his employees and clients (27).

Building occupational health has strong potential to **reduce unfair inequality, protect vulnerable groups, and support equal access** to healthcare. In many regions, the workplace has the potential to provide good, and sometimes the only, access to healthcare (either occupational or by employers providing / paying for primary healthcare). In addition, the obligatory nature of some occupational health programmes (such as health screenings or fitness for work examinations) can prevent employees who are less aware of / concerned for their health (which can be linked to a lower socio-economic status) from developing more illnesses vis à vis their “healthier” colleagues. Others have also emphasized the role of occupational health as a potential tool to reduce the health gap between high-income and low-income countries (13), or consider it as an instrument that can break the cycle of poverty, because it can drastically improve living conditions (18). Finally, occupational health resources have great potential in protecting more vulnerable populations, such as immigrant populations (75), different ethnicities (76), young employees, or female workers (77), who are often confronted with different hazards or are more at risk of injuries at work, while many of them are already at a disadvantage in other dimensions. The text box adjacent gives an example of such a vulnerable population (Nepalese immigrant workers) and their higher (unmet) need for occupational health care.



Nepalese immigrant workers

An example of a vulnerable occupational population is given in an article by Simkhada et al. (78). Their work focuses on Nepalese employees working abroad (primarily in Malaysia, the six Gulf Co-operation Council countries, and India), who are mostly engaged in semi-/ unskilled labour on building sites and factories, or in domestic work. These workers face high risks (discrimination, gender inequality, sexual exploitation, poor working and living conditions, limited access to health care) resulting in more than 1000 deaths per year (excluding India), and many workers returning home with mental and physical health problems. Studies indicate higher (fatal and non-fatal) occupational injury rates in construction and agriculture, poor protection for greenhouse pesticide workers (in Oman), and high prevalence of toxoplasmosis, compared to non-migrant workers (78).

Key messages

- There is a strong moral rationale for investing in OH
- OH programmes have the potential to reduce unfair inequality and support equal access to healthcare, to diminish the health gap between high-income and low-income countries, and to protect vulnerable groups

IV. Impact of global policy and regulation on occupational health

A. Worker compensation systems

Briefly mentioned previously, differences in **workers' compensation** (and social security) **systems** can have a strong impact upon the distribution of costs. While varying considerably (15, 29)^K, all compensation systems essentially aim to recompense the burden of (mostly occupational) disability, from injury or disease, or death, to the employee or dependants (79). They thereby often make the employee forgo litigation or provide automatic compensation without looking at aspects of "fault".

According to the International Labour Office, six systems can be discerned (79):

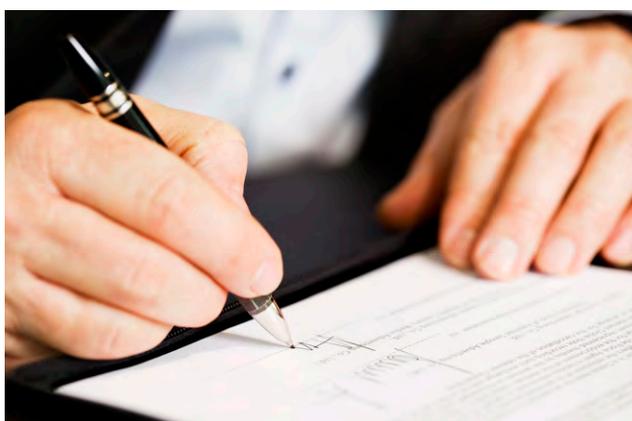
- A workers' compensation system: e.g. in the USA or Canada
 - With the obligation to provide benefits on the employer, possibly with (obliged) insurance coverage and corresponding (experience-rated) premiums
 - With (narrow) social insurance operated by a government department (often a ministry of labour)
 - With (narrow) social insurance operated by a government agency or "compensation board" that is (in theory) independent of ministerial control
- Social insurance or security: compensation is taken up together with unemployment, sickness, disability, retirement, and other payments, usually financed by (payroll) taxes
- Accident compensation: covers all accidents regardless of the cause and occupational diseases
- Sick pay: requires employers to pay a portion of wages (e.g. up to two years in the Netherlands)
- Disability insurance: employer organised group policy against disability
- Employers' liability: possibility for workers to legally claim compensation from employers

In the extreme cases, all payments may fall upon the employee (e.g. when no compensation system nor social security is in place and employers are difficult to litigate), on the employer (e.g. when the compensation is equal to or higher than the societal cost or the health burden and health care costs of the employee), or on society (e.g. when all is financed through taxes). In practice, most systems include mixed distribution between parties.

^K For instance, a review that examined differences of workers' compensation systems across three countries (USA states, Canada, and Australia), found variations in where employers can insure (private or state funds), whether self-insurance is allowed, whether certain sectors are excluded, whether there are limitations on medical treatment, choice of treating physician, length of disability benefits payment, whether mental problems are covered, or whether maximum coverage limits exist [7].

The different systems can also give rise to **additional costs**, such as higher insurance premiums for employers, dependent on the occupational risks or number of past accidents (i.e. experience-rating) (29). In turn, these differences can strongly affect the cost-effectiveness or financial returns from occupational health programmes, especially when looking from a narrower perspective (such as the employee's or the employer's).

In light of section II.C on the societal perspective, the preceding mechanisms can be seen as **“cost-shifting”**, as many let society bear the burden instead of the employee or internalize costs for the employer. After all, enterprises bear large responsibilities for occupational health but do not (automatically) bear the full burden of occupational health problems (29). However, the diversity they create makes it less straightforward to define (global) common grounds, to compare benefits of interventions across settings, or to publicly report changes in these variables. Nonetheless, when they are applicable, “direct costs” to employers (such as workers’ compensation expenses or insurance premiums) have proven very relevant in numerous evaluations of occupational health programmes, and can strongly determine cost-effectiveness results (54).



B. Standards and legislation

A number of standard-setting bodies created norms for a broad range of working conditions and occupational health issues (15). These standards are not always ratified by jurisdictions^L, but many of them are eventually adapted by national legislators (12, 13, 15), thereby allowing for the force of law to demand implementation. Meeting these standards and complying with legislation can thus have important financial and non-financial consequences. First, some countries introduced strong fines for non-compliance to occupational health standards. For instance, USA's Occupational and Safety Health Administration (OSHA) demands \$12,675 per “serious violation” (80)^M. But even when no fines (or legislation) are in place, implementing standards can give rise to many of the OH benefits previously mentioned, such as improved employee protection and health and firm productivity, and given the right public reporting they might be a persuasive tool to benefit corporate image. Given the fact that many standards are based upon the best available scientific evidence (15, 81), they can be a powerful instrument to indicate how health at work can be protected and improved.

Since an exhaustive discussion of (often industry- or country-specific) standards is beyond the scope of this document, this section focuses on the most important global standards. For further country-specific details, ILO publishes a high quality global database on occupational health and safety legislation, which provides a country-by-country discussion of the most relevant OH legislation (82).

^L Ratification is “an expression of the political will to undertake comprehensive and coherent regulatory, enforcement and promotional action” in the area covered by a standard or convention (15).

^M The impact of these fines on workers’ protection hinges upon the scope of the ratification of standards, and whether/how these are adopted in national law.

The **International Labour Organization (ILO)** has published a wide range of standards on working conditions, among which more than 40 standards on occupational health, which are either conventions – “legally binding international treaties that may be ratified by member states” – or recommendations - non-binding guidelines (83). They have no punitive measures when not followed through, and are inconsistently ratified: some developed countries ratified only few, while some developing countries ratified the most (15).

The **International Organisation for Standardization (ISO)** is the largest developer of global standards. 20 – 30 voluntary standards on occupational health are available, all of which are based on the best available scientific evidence (15, 81). Other standards are still under development, a process that can take up several years, especially when they have far-reaching consequences such as the upcoming ISO 45001 *Occupational health and safety management systems*^N. Topics include welding fumes (e.g. ISO 15011:2009), nanoparticles (e.g. ISO/TS 12901:2014), personal protective equipment (ISO 13.340), ergonomics (e.g. ISO/TS 26460:2014, ISO 6385:2016) and exposure to noise, heat or cold (e.g. ISO 12894:2001, ISO 15743:2008).

There also exists a large number of (national) standard-setting organisations that focus on **occupational exposure limits** (OEL), which define thresholds of maximum exposure for average workers without serious injury or illness (15). Prime examples are the American Conference of Government Industrial Hygienists (ACGIH) list of Threshold Limit Values, The International Program on Chemical Safety (IPCS), the aforementioned ISO, the International Atomic Energy Agency, or the Centers for Disease Control and Prevention in the USA.

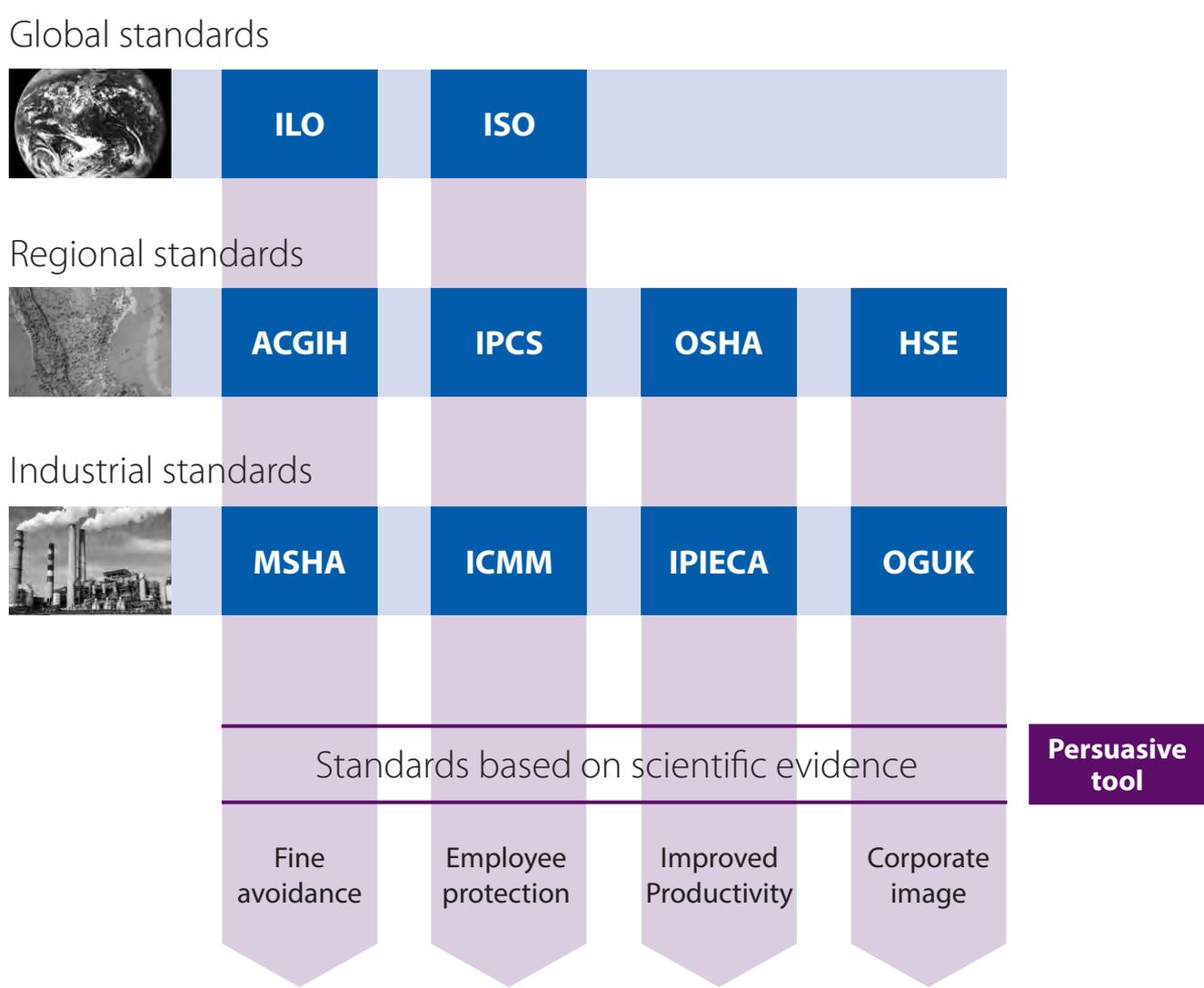
In addition, many **country or continent specific standards** (and naturally: legislations) exist that might prove inspirational to other countries or companies working globally. The risk-based system of the European Union, for instance, subjects all its member countries to laws and directives. These “range from the physical work environment (e.g. Directive 90/270/EC Display Screens), the psychosocial environment (Directive 2003/72/EC Employee Involvement) or basic employment conditions (Directive 93/104/EC Working Time)” (15). Other prime examples are the Occupational and Safety Health Administration (OSHA) for the USA, or the Health and Safety Executive (HSE) for the UK.

Finally, countless standards are **industry-specific**, and can therefore be set by the industry itself rather than national or standard-setting bodies. Some examples are MSHA and ICMM (mining), OGP IPIECA and OGUK (oil & gas UK), or the standards for shipping by the International Maritime Organisation (IMO).

Key messages

The value of OH interventions is strongly influenced by a country’s workers’ compensation and social security system. They can give rise to additional (avoidable) costs, and greatly influence the distribution of costs and effects across stakeholders. Meeting standards and complying with legislation can have important financial and non-financial benefits.

Figure 4 | The importance of standards – Opportunities/tools for return on occupational health investments



V. Future value of occupational health

As previously indicated, occupational health faces several challenges, and the near future will make many of them come to the fore more strongly: a significant global burden of occupational health problems, the ageing workforce, tackling new and emerging risks without neglecting existing risks, capacity building in developing countries, increased attention for the informal economy and small and medium enterprises (SMEs), etc.

Ambitious goals have been set to meet these challenges, and as the following paragraphs will indicate, some industries already take a proactive role in combatting these threats by supporting these goals or taking matters into their own hands.

One example is that the more health-aware enterprises today go beyond the minimum legislative requirements and bring **corporate social responsibility and sustainability** into practice. These two concepts express the commitment of enterprises to engage actively in the community in which it operates. This undertaking can take place on different levels – environmental, climate, (gender or other) equality, human rights, consumer protection, and also (occupational) health and safety. It reflects the fact that enterprises are intimately connected with their environment, with influence flowing in both directions. It also fits well with the vision that occupational health should focus on the broader well-being of workers: instead of a focus on physical health, mental and social aspects should be included when developing an occupational health strategy.

“Sustainable development aims to meet the needs of the present world population without causing adverse effect on health and on the environment, and without depleting or endangering the global resource base, hence without compromising the ability of future generations to meet their needs”

(WHO 1994).



The **Sustainable Development Goals** (SDGs) set by the United Nations are another example (85). Taken up in the 2030 Agenda for Sustainable Development, and adopted by a range of world leaders, these 17 goals aim to mobilize efforts to end poverty, fight inequalities and tackle climate change (86). Several of these 17 goals are relevant to occupational health, in particular Goal 3 “Good Health and Well-Being”, which includes reducing communicable and non-communicable diseases and other health hazards, and ensuring access to care. Recently, an effort has been made in the mining industry (87) and the oil and gas industry (88, 89), to commit to these goals and to inspire the worldwide industry to incorporate relevant SDGs into their business. For instance, the Atlas developed for the oil and gas industry incorporates guidance on integrating goals into core business, such as reducing occupational risks, protecting workers against (infectious and non-communicable) diseases, addressing mental health and substance abuse, etc (88).

In this context, it can greatly help to adhere to guidelines to achieve high quality and globally standardized **public reporting of corporate sustainability**, such as the Global Reporting Initiative (GRI) (28, 90). GRI helps businesses and governments worldwide understand and communicate their impact on critical sustainability issues such as climate change, human rights, governance and social well-being. This enables real action to create social, environmental and economic benefits for everyone. For enterprises working across the globe, an important challenge therein is to balance global reporting with programmes adapted to the local context (28). This can be achieved by defining and reporting global goals in the corporate strategy, and subsequently adapting these to local contexts to ensure applicability, and to allow local employees’ participation in OH programmes. A similar strategy has been implemented by the World Health Organization (WHO), which defines six different interpretations of their (global) concept of a “healthy workplace”^o, depending on the continent, each with

^o The global definition by the WHO is as follows: “A healthy workplace is one in which workers and managers collaborate to use a continual improvement process to protect and promote the health, safety and well-being of all workers and the sustainability of the workplace by considering the following, based on identified needs: health and safety concerns in the physical work environment; health, safety and well-being concerns in the psychosocial work environment including organisation of work and workplace culture; personal health resources in the workplace; ways of participating in the community to improve the health of workers, their families and other members of the community” (15).

their own local accents (15). Burton et al described regional interpretations in 2010 (7). In Africa, the main focus of “healthy workplaces” lies upon the physical work environment and addressing traditional occupational health and safety issues (e.g. pesticides) (7). Likewise, priorities of healthy workplaces in the Eastern Mediterranean deal with the physical work environment. However, the informal sector, gender issues, and small enterprises have been identified as of particular concern. In addition, this regional office published a series of “Health Education Through Religion” booklets on health (health promotion, health care ...) in the context of Islamic Law. South-East Asia has the highest regional burden of disease attributable to occupational risk factors (workplace injuries, exposure to carcinogens, dust, noise, and ergonomic factors). In response, “healthy workplaces” focus on national policy and plans of action (with special emphasis on the informal sector) and providing basic occupational health services (through linkage with the primary health care system). However, some individual countries have embarked on comprehensive healthy workplace initiatives (e.g. India). The USA’s efforts have focused on two areas: traditional occupational health and safety and the physical work environment (in response to strong labour legislation and enforcement), and workplace health promotion (with the aim of changing the lifestyles of employees to thereby reduce health care costs of employers). Next, the European Union has a wide range of comprehensive approaches to healthy workplaces from different groups and networks of Member States, enterprises and institutions that all address occupational health (e.g. EU-OSHA) with a unique focus. Some deal with traditional aspects (physical, chemical, biological, ergonomic or mechanical risks), others with the psychosocial environment and organisational culture, but all make a strong connection between the health of employees, the health of the enterprise, and the health of the community. Finally, in the Western Pacific, the global

definition of a “healthy workplace” is extended by four other aims: “ensure that health promotion and health protection become an integral part of management practices; foster work styles and lifestyles conducive to health; ensure total organisational participation; extend positive impacts to the local and surrounding community & environment” (7).

Finally, it is evident that meeting these challenges often blurs the line between public and occupational health. Implementing an effective occupational health strategy can therefore become an opportunity to help ameliorate workers’ and community members’ well-being beyond protecting them from occupational hazards. A good example of the private sectors’ commitment to this field is the Workplace Wellness Alliance (under the World Economic Forum): “a consortium of companies committed to advancing wellness in the workplace” (90). Moving beyond minimum national requirements and incorporating wellness aspects at work has the potential to contribute to a sustainable healthy and productive workforce, when these aspects are well designed and executed (see section VI.E on health promotion evidence).

Key messages

The workplace health agenda can broaden its scope beyond traditional occupational medicine, and include workplace wellness, sustainability, and corporate social responsibility. Leading industries have already seized this opportunity by taking occupational health beyond minimum national legal requirements, and offering guidance to others to expand the value of occupational health to these dimensions in the future.



VI. Occupational health: the evidence

The synthesis of scientific evidence in this section is based upon the latest systematic reviews of effectiveness and cost-effectiveness studies.

The distinction between the two types of research thereby lies in whether they take up economic variables in their analysis. “Cost-effectiveness research” includes an analysis of the costs of an intervention, or discusses the effect of an intervention upon economic variables (such as the effect upon absenteeism).^P “Effectiveness research” does not look at the costs of interventions or their effect upon economic variables, but focuses on an intervention’s health effects, reductions in exposure, etc. Effectiveness research thus allows firms to identify the most beneficial interventions, and cost-effectiveness research can indicate the interventions with the best value-for-money, by comparing the costs of programmes with their effects.^Q

As described in the Appendix, the reviews were identified through systematic searches on two objectives: historical exposures and rising challenges. The sections below reflect these objectives, and supplement the evidence with relevant case studies.

The reductions in workplace fatality rates in many countries show that many successful interventions are put into practice every day, without ever been proven in a scientific study or taken up in a Cochrane review (15). The precautionary principle from the World Health Organization is a useful addition to this observation: *“The principle states that, in the case of serious or irreversible threats to the health of humans or the ecosystem, acknowledged scientific uncertainty should not be used as a reason to postpone preventive measures.”* In other words, *in the context of this paper, employers and workers should not delay implementations to improve workplace conditions and promote health simply because there is no strong scientific evidence of the intervention’s effectiveness”* (15). Note furthermore that the absence of conclusive evidence does not necessarily mean that the intervention under consideration is ineffective, but often shows that further research is needed.



^P For instance, full economic evaluations compare alternatives in terms of both costs/resources and consequences/outcomes/effects (41).

^Q Note that the latter can be left in natural units (e.g. life years gained) or monetized, thus allowing for direct comparisons with costs or other interventions. A well-known strategy is to describe the conclusion in an estimate of return on investment (ROI). The case studies in this section will often be instances of the latter, but note that ROI estimates can hide a very large diversity, since it does not indicate what is included or left out.

A. Risk assessment and hazard control

In the field of hazard control and exposure reduction, (cost-)effectiveness studies can be difficult to carry out (e.g. due to ethical restrictions on experimental trials) and are consequently not always available (92-95). However, this does not mean that the necessary evidence for action is lacking. First, by establishing the link between exposure and health, the (epidemiological) literature has demonstrated the harmful effects of many occupational hazards (e.g. (96-107)). Second, many cost-of-illness studies have been performed to indicate the financial burden of related occupational diseases, and to demonstrate which health problems are most pressing. In conclusion, even when only epidemiological studies are available on certain hazards, action can and should be undertaken (as is also advocated by the WHO in the precautionary principle) to reduce these harms and financial burdens. In what follows, we will synthesize the effectiveness and cost-effectiveness of OH interventions related to (physical, chemical and biological) agents, the work environment, or ergonomic risks.

1. Physical and chemical hazards in the workplace environment

Evidence on interventions against physical and chemical hazards in the workplace is presented in Table 2 below. Overall, nineteen reviews stated evidence for the effectiveness of interventions, four for cost-effectiveness, twelve saw inclusive or inconsistent evidence, and seven reviews found no evidence for effectiveness. The following sections focus in more detail on interventions against hazardous agents, exposure to hazards in the air and related respiratory diseases, carpal tunnel syndrome, interventions

related to noise and voice disorders, on mitigating the psychological effects of the work environment and on allergies and contact dermatitis^R. Note that in Table 2 (and following tables) multiple reviews can support a single key message, and that key messages of a different nature (e.g. one stating cost-effectiveness and one stating insufficient evidence) are separated in different rows.

a) Agents

Our searches did not find much research on the effectiveness of interventions that limit or avoid exposure to agents due to ethical restrictions as mentioned earlier. Positive evidence was found for asbestos screening (108) and for the cost-effectiveness of chromate lung cancer surveillance (109). Most studies in this field rather point to the need for more research before strong conclusions can be drawn.

b) Air / respiratory diseases

The next group of reviews studied how harmful effects of agents in the air can be mitigated or avoided, and whether this can reduce the incidence of respiratory diseases.

Effectiveness: Table 2 indicates that there is some debate between reviews whether reducing exposure to asthma-inducing agents is effective: one review (110) saw no evidence, while two others saw positive evidence (111)*(112)*. Removal from exposure has a stronger evidence base, but also has its limits: it was associated with an increased risk of unemployment (111)*.

A more specific review noted that air filtration was effective in reducing concentrations of particulate matter^S in animal indoor environments (113).

R "Occupational irritant hand dermatitis is an inflammatory reaction of the skin occurring in people who regularly come into contact with water, detergents, chemicals, and other irritants during their working day" (144).

S "Air in animal facilities has a higher portion of biological content than does air in other environments, the adverse health impact is much greater than it is for the same amount of particulate matter in other environment" (113).

Cost-effectiveness: Two reviews examined the cost-effectiveness of interventions in this field. One review noted that unmanned aerial systems (“drones”) are potentially a cost saving tool in assisting occupational hygienists in environmental monitoring, emergency response, epidemiology, safety, and industrial process optimization (114), where “potentially” refers to the fact that the conclusions are based on an extrapolation from allied disciplines. The other review studied several interventions that aim to prevent silicosis^T, and found that engineering control programmes (e.g. wetting a drilled surface to avoid silica dust inhalation) are cost-effective in both developed and developing countries: the cost per healthy year gained ranged from \$105.89 to \$109.35 (115).

c) Noise and voice disorders

A significant number of reviews studied interventions that aim to reduce the incidence of voice disorders and the effects of noise. No cost-effectiveness evidence was found, but there is effectiveness evidence for several interventions.

Tinnitus: Although the majority of the reviews discussed interventions related to managing or treating tinnitus (8 out of 11 reviews), only two indicated evidence for effectiveness: cognitive behavioural therapy (111)*, and tinnitus retraining therapy (112)*, while the latter found only one low-quality RCT.

Hearing loss: One review (116)* indicated several effective, albeit based on lower quality evidence, interventions to reduce noise or prevent hearing loss: implementing stricter legislation, training of proper insertion of earplugs, and better use of hearing protection devices as part of hearing loss prevention programmes (116)*.



CASE STUDY

Workplace engineering noise control

After testing, a manufacturer of menthol crystals in Singapore found that a centrifugal and sieving machine produced excessive noise – fluctuating sound that exceeds the equivalent sound pressure level of 85 dBA over an 8-hour workday – to which 8 employees had direct exposure. The production process was altered, replacing the existing machines with two heaters, each at a cost of \$13,000, with a total noise reduction of 19 dBA. Accounting for capital recovery and with an expected life of 10 years, the annual cost is estimated at \$3404.54. Before the substitution, the company spent \$1000 on noise monitoring (every 3 years), \$100 on hearing conservation training (every 3 years), and \$160 on occupational health (including yearly audiometric screenings), giving an annualized occupational health cost total of \$643.33. Gains in lost work time were estimated at \$296.80 using average hourly wages, and productivity increases of 25% were observed, giving rise to an annualized gain in increased productivity of \$44,096. The overall cost, net of avoided occupational health costs, lost work time, and productivity gains, was \$41,631.59, with a benefit to cost ratio of 13.23 (119)

T “Silica is a major component of sand, granite, quartz, and most stone [...] Inhaling silica dust causes scarring of lung tissue, which impairs breathing, and may eventually result in death” (115)

U “Direct techniques focus on the underlying physiological changes needed to improve an individual’s technique in using the vocal system whereas indirect techniques concentrate on contributory and maintenance aspects of the voice disorder (such as lack of knowledge).” (117)

V “Functional dysphonia” is a voice problem in the absence of any obvious physical condition.

Voice: Finally, one review found evidence for the effectiveness of voice-related interventions: comprehensive voice therapy comprising both direct and indirect therapy elements^v was effective in reducing functional dysphonia^u (117)*, but not in the prevention of voice disorders (118)*.

d) Carpal Tunnel Syndrome (CTS)

Carpal Tunnel Syndrome is a disorder in the nervous system that can be work-related. No cost-effectiveness evidence was found, but there was evidence of effectiveness in several reviews. However, many relate to the treatment of CTS, which can go beyond the occupational health setting.

- Local corticosteroid injection^w provides clinical improvement in symptoms (120)*
- Short-term benefit from oral steroids, splinting (at night (121)*), ultrasound, and yoga (122)*
- (limited evidence for) exercise and mobilisation interventions (e.g. carpal bone mobilisation or wrist orthosis immobilisation) (122)* (123)*
- (limited evidence for) therapeutic ultrasound (124)*
- (limited evidence for) multiple rehabilitation treatments (dressings, controlled cold therapy, ice therapy, multi-modal hand rehabilitation, laser therapy, electrical modalities, scar desensitisation, and arnica) (125)*
- surgical treatment (compared to splinting) (126)*

e) Psychological effects of the work environment

Two reviews investigated the hypothesis that the work environment is capable of affecting the mental health of employees. One (127)* specifically focused on how changing the physical healthcare environment,

aimed primarily at improving the health and well-being of patients (e.g. a renovated ward in a hospital), affects the mental health of the nurses and physicians that care for these patients. It found no evidence to support or refute an impact. The other review (128) examined the impact on mood disorders and suicide of a broad range of factors: physical, chemical and biological agents, work organisation (e.g. shift work), psychological work environment (e.g. work stress), and social environment (e.g. the relationship with colleagues). The authors saw epidemiological evidence in diverse areas (linking the above factors to increased risks), and indicated effective and cost-effective interventions across these different fields.

f) Allergies and contact dermatitis

Allergies: Concerning allergies at the workplace, there is evidence for the effectiveness of immunotherapy (149), and biological treatments (149). For latex allergy, there is evidence for the effectiveness of low-allergen no powdered natural-rubber latex (NRL) allergy gloves for healthcare workers (150), and substitution of powdered latex gloves with low protein powder-free NRL gloves on latex-free gloves (151).

Dermatitis: For hand dermatitis, one review indicates evidence for the effect of prevention programmes on lowering occurrence, improving adherence to preventive measures, and improving clinical outcomes and self-reported outcomes (152).

W "Local corticosteroid injection is a common non-surgical treatment for carpal tunnel syndrome" (120)*.

Table 2 | Evidence on physical and chemical components in the workplace environment

[asterisks (*) = Cochrane systematic review, CE = cost-effectiveness, E = effectiveness, IE = inconsistent or inconclusive evidence of effectiveness, ICE = inconsistent or inconclusive evidence of cost-effectiveness, NE = no evidence for effectiveness, NCE = no evidence for cost-effectiveness. Inconsistent, inconclusive, or no effective evidence can pertain to an intervention as a whole or only certain outcomes (not) associated with it]

FOCUS	KEY FINDINGS	REVIEW
Agents		
Asbestos	E: Low dose CT screening is effective (in the studied setting) in identifying early stage lung cancer	(108)
Chrome	CE: For chromate lung cancer surveillance, total cost divided by survival years was €315 per year	(109)
Mercury	IE: More research is needed	(93, 108)
Nanotechnology	IE: While conclusions of most papers concerning the benefits of clinical implementation were promising, actual clinically relevant applications were rarely encountered ICE: Evaluation of financial and organisational aspects is often missing	(129)
Alkalinisation for organophosphorus pesticide poisoning	IE: Preliminary studies suggest benefit from blood alkalinisation with NaHCO ₃ in OP poisoning, but there is insufficient evidence to support its routine clinical use. Further research is required	(99)*
Urinary alkalinisation for acute chlorophenoxy herbicide poisoning	IE: Insufficient evidence to support the routine use of urinary alkalinisation for acute chlorophenoxy herbicide poisoning. Further research is required to determine efficacy	(130)*
Air		
Mould	E: The repair of mould-damaged houses and offices decreases asthma-related symptoms and respiratory infections	(112)*
Particulate matter (PM) in animal indoor environments ^x	E: Filtration studies have shown efficiencies of approximately 50% in removing PM concentration	(113)
	IE: The effect of ventilation on PM concentration remains unclear	(113)
Unmanned Aerial Systems in Occupational Hygiene	CE: Literature from allied fields indicates that application in occupational hygiene could lead to cost savings, time savings, and averting hazardous environments via remote sensing	(114)
Workplace interventions for treatment of occupational asthma	E: Very low-quality evidence that removal from exposure improves asthma symptoms and lung function compared with continued exposure. Reducing exposure also improves symptoms but seems not as effective as complete removal. However, removal from exposure is associated with an increased risk of unemployment, whereas reduction of exposure is not. More research is needed to identify the most beneficial interventions	(111)*
Reduction of exposure in the management of occupational asthma	NE: Available data indicates that a reduction of exposure to the agents causing occupational asthma cannot be routinely recommended as an alternative to complete avoidance	(110)

X "Air in animal facilities has a higher portion of biological content than does air in other environments, the adverse health impact is much greater than it is for the same amount of particulate matter in other environment" (113).

Behavioural interventions to promote workers' use of respiratory protective equipment	NE: Very low quality evidence that behavioural interventions, namely education and training, do not have a considerable effect on the frequency or correctness of RPE use in workers Quality: Studies had methodological limitations, and more research is required to make strong conclusions on effectiveness	(131)*
Noise, hearing loss, and voice disorders		
Interventions to prevent occupational noise-induced hearing loss	E: Very low-quality evidence that implementation of stricter legislation can reduce noise levels in workplaces. Moderate-quality evidence that training of proper insertion of earplugs significantly reduces noise exposure at short-term follow-up but long-term follow-up is still needed. Very low-quality evidence that the better use of hearing protection devices as part of hearing loss prevention programmes reduces the risk of hearing loss	(116)*
Cognitive behavioural therapy (CBT) for tinnitus	E: Six studies demonstrated a significant improvement in depression score and five studies in quality of life (decrease of global tinnitus severity), suggesting that CBT has a positive effect on the management of tinnitus. No evidence of a significant difference in the subjective loudness of tinnitus	(132)*
	NE: No evidence of a significant difference in the subjective loudness of tinnitus	(132)*
Tinnitus retraining therapy (TRT)	E: Only one low-quality RCT was included, but this study suggested that TRT is much more effective as a treatment for patients with tinnitus than tinnitus masking	(133)*
Antidepressants for patients with tinnitus	IE: Insufficient evidence to say that antidepressant drug therapy improves tinnitus	(134)*
Amplification with hearing aids for patients with tinnitus and co-existing hearing loss	IE: Only one study was included, no evidence to support or refute their use	(135)*
Sound therapy (masking) in the management of tinnitus in adults	IE: No strong evidence of the efficacy of sound therapy in tinnitus management due to limited data and lack of quality research	(136)*
Repetitive transcranial magnetic stimulation (rTMS) for tinnitus	IE: Very limited support for the use of low-frequency rTMS for the treatment of patients with tinnitus, studies do suggest that it is a safe treatment in the short-term More research is needed	(137)*
Ginkgo biloba for tinnitus	NE: Limited evidence does not demonstrate that Ginkgo biloba is effective for tinnitus when this is the primary complaint	(138)*
Anticonvulsants for tinnitus	NE: No evidence from studies performed so far to show that anticonvulsants have a large positive effect in the treatment of tinnitus but a small effect (of doubtful clinical significance) has been demonstrated	(139)*
Interventions for treating functional dysphonia in adults	E: Evidence for effectiveness of comprehensive voice therapy comprising both direct and indirect therapy elements. Effects are similar in patients and in teachers and student teachers screened for voice problems Quality: Possible publication bias, more high-quality research is needed	(117)*
Interventions for preventing voice disorders in adults	NE: No evidence that either direct or indirect voice training or the two combined are effective in improving self-reported vocal functioning when compared to no intervention	(118)*

Carpal Tunnel Syndrome (CTS)		
Local corticosteroid injection for carpal tunnel syndrome	E: Local corticosteroid injection for carpal tunnel syndrome provides greater clinical improvement in symptoms one month after injection compared to placebo	(120)*
Non-surgical treatment (other than steroid injection) for carpal tunnel syndrome	E: Significant short-term benefit from oral steroids, splinting, ultrasound, yoga and carpal bone mobilisation More trials are needed	(122)*
Splinting for carpal tunnel syndrome	E: Limited evidence that a splint worn at night is more effective than no treatment in the short term Insufficient evidence regarding the effectiveness and safety of one splint design or wearing regimen over others, and of splint over other non-surgical interventions for CTS. More research is needed	(121)*
Exercise and mobilisation interventions for carpal tunnel syndrome	E: Limited and very low-quality evidence of benefit for a diverse collection of exercise and mobilisation interventions for CTS	(123)*
Therapeutic ultrasound for carpal tunnel syndrome	E: Poor quality evidence from very limited data to suggest that therapeutic ultrasound may be more effective than placebo More high-quality research is needed	(124)*
Rehabilitation following carpal tunnel release	E: Limited and, in general, low quality evidence for the benefit of multiple rehabilitation treatments, including immobilisation using a wrist orthosis, dressings, exercise, controlled cold therapy, ice therapy, multi-modal hand rehabilitation, laser therapy, electrical modalities, scar desensitisation, and arnica. More high-quality research is needed	(125)*
Surgical versus non-surgical treatment for carpal tunnel syndrome	E: Surgical treatment of carpal tunnel syndrome relieves symptoms significantly better than splinting	(126)*
Ergonomic positioning or equipment for treating carpal tunnel syndrome	IE: Insufficient evidence from randomised controlled trials to determine whether ergonomic positioning or equipment is beneficial or harmful for treating carpal tunnel syndrome	(140)*
Surgical treatment options for carpal tunnel syndrome	NE: No strong evidence supporting the need for replacement of standard open carpal tunnel release by existing alternative surgical procedures for the treatment of carpal tunnel syndrome	(141)*
Allergies and contact dermatitis		
Allergen immunotherapy and biological treatments applied to occupational allergy	E: Data is scarce, but suggests that immunotherapy and biological treatments may allow allergic workers to continue their work activity. Quality: further studies are needed	(149)
Natural-rubber latex (NRL) allergy in health care workers	E: Use of low-allergen, nonpowdered NRL gloves substantially reduces airborne exposure to latex in most health care settings	(149, 150)
Primary prevention of latex related sensitisation and occupational asthma	E: Substitution of powdered latex gloves with low protein powder-free NRL gloves or latex-free gloves greatly reduces NRL aeroallergens, NRL sensitisation, and NRL-asthma in healthcare workers Quality: ranked SIGN level 2+, small and largely observational evidence base	(150, 151)
Prevention programmes for hand dermatitis	E: Moderate evidence for the effect of prevention programmes on lowering occurrence and improving adherence to preventive measures, and low evidence for the effect on improving clinical outcomes and self-reported outcomes. CE: No studies reporting on costs were found	(152)
Interventions for preventing occupational irritant hand dermatitis	IE: Insufficient evidence. generally positive, but no statistical significance	(144)*

Other		
Ultraviolet radiation	IE: Education and policy approaches to increasing sun-protective behaviours were effective in some settings (primary schools and recreational or tourism settings), but there was insufficient evidence to determine effectiveness when implemented in occupational settings	(142)
Non-pharmacological interventions for preventing venous insufficiency in a standing worker population	E: Low evidence that compression stockings improved symptoms of leg fatigue in standing workers Quality: Only one study with high risk of bias was found	(143)*
Work environment & psychology		
Impact of work environment on mood disorders and suicide	E & CE: Increasing numbers of clinical trials have shown favourable effects of interventions and suggested preferable return-on-investment results	(128)
The psychological effects of the physical healthcare environment on healthcare personnel	IE: Since only one study was included, the authors concluded that there was insufficient evidence to support or refute the impact of the physical healthcare environment on work-related outcomes of healthcare staff	(127)*

f) Conclusion

To summarize the main conclusions of these sections: many of these fields would benefit from more research. Overall, there was little cost-effectiveness research. Regarding effectiveness, little evidence was available on interventions against hazardous agents, with asbestos and chrome as exception. In the field of air and respiratory diseases there is some debate between reviews whether reducing exposure to asthma-inducing agents is effective (110) (111)*(112)*, and while removal from exposure seems more effective, it also has its drawbacks (111)*. Next, several reviews discussed tinnitus, but only two indicated effectiveness: cognitive behavioural therapy (132)* and tinnitus retraining therapy (133)*. More evidence was available for the use of hearing loss prevention intervention (116)* and for treating functional dysphonia (117)*. The evidence on carpal tunnel syndrome treatment seems largely positive, but it should be noted that these were often based on limited evidence. Finally, regarding psychological effects of the work environment, more evidence is needed to identify the best interventions.

2. Biological agents and infectious diseases

The evidence on biological agents and infectious diseases at work is summarized in Table 3 and divided into four categories: percutaneous exposure (exposure through the skin), hepatitis, human immunodeficiency virus (HIV), and (four) other interventions. Most of the evidence in this section came from the healthcare sector, with only four exceptions: one review on hepatitis A vaccination in food service workers (145)*, and three on HIV in sex-workers (146)*(147)*(148)*. Overall, the evidence base looks largely positive: ten reviews found evidence for the effectiveness of the studied interventions, two for cost-effectiveness, six reviews observed inconsistent or inconclusive evidence, and one review did not find evidence for effectiveness. Many of these reviews found only limited evidence and say more high-quality research is needed.

Percutaneous exposures: Several reviews saw beneficial effects of interventions against percutaneous exposures in healthcare staff. There was effectiveness evidence for safe passive intravenous systems (but moderate quality evidence that active systems may increase exposure to blood)(153)*, double (and to a lesser extent: triple) gloving (154)*, and blunt needles for surgical staff (155)*. There was also cost-effectiveness evidence that the costs of preventive measures against needlestick injuries may be offset by the benefits (106).

Body fluids: One review also indicated that in the case of preventing highly infectious diseases due to exposure to contaminated body fluids, more breathable types of personal protective equipment (PPE) may not lead to more contamination but may have greater user satisfaction. It also noted that double gloving is more effective, and saw a benefit in more active training to use PPE (156)*.

Hepatitis: Four reviews discussed interventions concerning hepatitis. Two of these studied the cost-effectiveness of different strategies. First, vaccinating against hepatitis A is supported for food service workers (\$13,969 per saved life year) (145)*. Second, substituting hepatitis A-B vaccine for hepatitis B vaccine is a dominant strategy for healthcare and public safety workers in the western US (158)*. Further evidence is available for the effectiveness of hepatitis B vaccination in healthcare workers (both for plasma-derived vaccines and recombinant vaccines) (159)*.



CASE STUDY

Sharps injuries among health care workers

The Vanderbilt University Medical Center in Nashville (USA) was faced with a substantial number of needlestick injuries in their personnel. A committee reviewing the problem found one of the causes to be the “straight-drop” system in containers, which allowed staff to stuff extra needles in an already full box. After testing two other sharps containers, a new system was implemented in collaboration with the manufacturer. This resulted in reductions of needlestick injury rates by two-thirds, represented by total cost savings to the Medical Center of more than \$62,000 a year (157).

CASE STUDY**Vaccination against influenza among the Clermont-Ferrand University Hospital staff**

A study in the Clermont-Ferrand University Hospital in France compared the cost of vaccinating hospital personnel (medical and non-medical staff) with the cost of sick leave among vaccinated and non-vaccinated employees in 2003, 2004, and 2005 (with respective vaccinal coverage of 13%, 20.5%, and 30.1%). In 2005, the cost of vaccination per vaccinated employee was €4.02. The mean duration of sick leave among vaccinated staff in 2003, 2004 and 2005 was 0.16, 0.17, and 0.18 days, while it was 0.26, 0.39, and 0.34 among non-vaccinated staff. This resulted in a benefit per vaccinated employee of €5, €26, and €20 per year, and a total benefit for the institution of €86,458 (160).



CASE STUDY

Rapid HIV test

HIV: Concerning occupational exposure to HIV, no cost-effectiveness evidence was found, but four reviews found evidence of effectiveness. First, there is evidence for the effectiveness of behavioural interventions among sex workers in high-income countries (146)*, and female sex workers in low- and middle-income countries (147)*. It is also recommended by one study to initiate a four-week regimen of antiretroviral post-exposure prophylaxis (a way to prevent HIV infection after exposure) as soon as possible after occupational exposure to HIV (161)*. Finally, voluntary counselling and testing (VCT) offered at the work site seems to increase the uptake of testing (148)*, and there is (low quality) evidence that educational interventions decrease sexually transmitted diseases, unprotected sex, and sex with commercial sex workers (but not sex with multiple partners and the use of alcohol before sex) (148)*.

Although exposure of healthcare workers to blood should be limited as much as possible, there is still the possibility that occasional exposure occurs. This opens the need for tests that evaluate whether the healthcare worker has been exposed to HIV. A study (64) compared the standard enzyme-linked immunosorbent assay (ELISA) HIV test, against a rapid human immunodeficiency virus (HIV) test in a university-based trauma centre with 404 beds. Evaluating the costs of laboratory tests, postexposure prophylactic medications, and estimated lost work time, it was found that the ELISA test would have resulted in a cost of \$5965.81, while the rapid test resulted in \$465.80. The latter thus results in substantial cost savings (64).

Table 3 | Evidence on biological agents

[asterisks (*) = Cochrane systematic review, CE = cost-effectiveness, E = effectiveness, IE = inconsistent or inconclusive evidence of effectiveness, ICE = inconsistent or inconclusive evidence of cost-effectiveness, NE = no evidence for effectiveness, NCE = no evidence for cost-effectiveness. Inconsistent, inconclusive, or no effective evidence can pertain to an intervention as a whole, or only certain outcomes (not) associated with it]

FOCUS	KEY FINDINGS	REVIEW
Percutaneous exposure		
Devices for preventing percutaneous exposure injuries caused by needles in healthcare personnel	E: Safe passive intravenous systems: very low quality evidence of a decrease in NSI and a reduction in the incidence of blood leakage events (but moderate quality evidence that active systems may increase exposure to blood). There was low to moderate quality evidence that introduction of legislation probably reduces NSI rates	(153)*
	IE: Safe blood collection systems: very low-quality evidence of inconsistent effects on needlestick injuries (NSIs). Safe passive intravenous systems: moderate quality evidence that active systems may increase exposure to blood. Safe injection needles: the introduction of multiple safety devices or the introduction of sharps containers the evidence was inconsistent or there was no clear evidence of a benefit. More high-quality research is needed	(153)*
Needlestick injuries and sharps injury management	CE: The authors conclude that NSIs generate significant direct, indirect, potential, and intangible costs, possibly increasing over time, and the costs of preventive measures may be offset by the benefits	(106, 153)
Gloves, extra gloves or special types of gloves for preventing percutaneous exposure injuries in healthcare personnel	E: Moderate-quality evidence that double gloving compared to single gloving during surgery reduces perforations and blood stains on the skin, indicating a decrease in percutaneous exposure incidents. Low-quality evidence that triple gloving and the use of special gloves can further reduce the risk of glove perforations compared to double gloving with normal material gloves. Further studies are needed to evaluate the effectiveness and cost-effectiveness of special material gloves and triple gloves, and of gloves in other occupational groups	(154)*
Blunt versus sharp suture needles for preventing percutaneous exposure incidents in surgical staff	E: High quality evidence that the use of blunt needles appreciably reduces the risk of exposure to blood and bodily fluids for surgeons and their assistants over a range of operations	(155)*
Hepatitis		
Vaccinating food service workers against hepatitis A infection	CE: A vaccination policy would cost the health care system \$13,969 per saved life year, which might exceed accepted standards	(145)*
Hepatitis A-B vaccine versus hepatitis B vaccine for healthcare and public safety workers in the western United States	CE: Substituting hepatitis A-B vaccine for hepatitis B vaccine is a dominant strategy since it would provide improved health outcomes and economic savings. The cost-effectiveness improved as the time horizon was extended. In the base-case scenario, the financial benefits outweighed the costs at year 11	(158)*
Vaccines for preventing hepatitis B in health-care workers	E: Plasma-derived vaccines (PDV) significantly prevents hepatitis B events, Recombinant vaccines seem to be able to elicit similar protective anti-HBs levels	(159)*
Hepatitis B vaccination in healthcare workers	E: Highly effective in preventing hepatitis B infection	(159)

Postexposure prophylaxis (PEP) after hepatitis C virus (HCV) occupational exposure in the interferon-free era (healthcare personnel)	IE: Insufficient supporting data exist to endorse the use of directly acting anti-HCV (Direct Acting Antivirals) for PEP after HCV occupational exposures	(159, 160)
HIV		
Behavioural interventions to reduce the transmission of HIV infection among sex workers and their clients in high-income countries	E: Limited evidence from randomised controlled trials for the effectiveness of behavioural interventions to reduce the transmission of HIV infection among sex workers and their clients in high-income countries. More high-quality research is needed	(146)*
Behavioural interventions to reduce the transmission of HIV infection among sex workers and their clients in low- and middle-income countries	E: Compared with standard care or no intervention, behavioural interventions are effective in reducing HIV and the incidence of STIs amongst female sex workers (FSWs)	(147)*
Antiretroviral post-exposure prophylaxis (PEP) for occupational HIV exposure	E: RCTs will not plausibly be implemented, but on the available evidence the authors recommend to initiate a four-week regimen of PEP as soon as possible after exposure, depending on the risk of seroconversion, and that healthcare workers should be counselled about adverse events and their management	(161)*
Interventions to reduce risky sexual behaviour for preventing HIV infection in workers in occupational settings	E: Moderate quality evidence that voluntary counselling and testing (VCT) offered at the work site increases the uptake of testing. Even though this did not lower HIV-incidence, there was a decrease in self-reported sexual transmitted diseases and a decrease in risky sexual behaviour. Low quality evidence that educational interventions decrease sexually transmitted diseases, unprotected sex and sex with commercial sex workers but not sex with multiple partners and the use of alcohol before sex Quality: More high-quality research is needed	(148)*
HIV infection following occupational exposure	IE: Data is currently inadequate to define the appropriate role of zidovudine (ZDV), an antiretroviral agent for treating HIV infection, in preventing HIV infection following occupational exposure	(148, 163)
Prevention of occupational transmission of HIV in healthcare settings	IE: The authors noted that workers' compliance to recommended measures was relatively poor. The effectiveness and cost-effectiveness of universal precautions and body substance isolation remain to be demonstrated. Testing patients for HIV infection and other blood-borne pathogens does not appear to be a more appropriate solution	(164)
Other		
Personal protective equipment (PPE) for preventing highly infectious diseases due to exposure to contaminated body fluids in healthcare staff	E: Very low-quality evidence that more breathable types of PPE may not lead to more contamination, but may have greater user satisfaction. Very low-quality evidence that double gloving and CDC doffing guidance appear to decrease the risk of contamination and that more active training in PPE use may reduce PPE and doffing errors more than passive training. Quality: Studies had high risk of bias, more research is needed	(156)*
Interventions for preventing the spread of infestation in close contacts of people with scabies	IE: No trials could be included due to insufficient quality, effects of providing prophylactic treatments for contacts of people with scabies to prevent infestation thus remain unknown	(165)*
Influenza vaccination for healthcare workers (HCW) who care for people aged 60 or older living in long-term care institutions	IE: No conclusive evidence of benefit of HCW vaccination programmes on specific outcomes of laboratory-proven influenza, its complications (lower respiratory tract infection, hospitalisation or death due to lower respiratory tract illness), or all-cause mortality in people over the age of 60 who live in care institutions. High quality research (RCTs) are needed to avoid risk of bias	(166)*
Antibiotic prophylaxis for leptospirosis [†]	NE: Regular use of weekly oral doxycycline 200 mg increased the odds of adverse effects (nausea and vomiting), while benefits were unclear	(167)*

3. Injury prevention (without biological agents)

The searches found only sparse evidence on injury prevention at work. Three reviews observed evidence for effectiveness, one for cost-effectiveness, one review saw inconsistent or inconclusive evidence, and two reviews indicated no evidence for the effectiveness of the studied intervention (Table 4).

Effectiveness: Looking at Table 4 in more detail, evidence for the effectiveness of injury prevention at work is available for company-oriented safety interventions in construction workers (such as a multifaceted safety campaign and a multifaceted drug workplace programme) (168)*, and continuing company-oriented interventions among management and construction workers seems to have an effect in the long term (168)*. Finally, graduated driver licensing was seen to be effective in reducing crash rates among young drivers (169)*.

Cost-effectiveness: One review looked at the productivity impact of caffeine and found that it has an effect on the performance of shift workers. However, the effect upon injury rates remains unknown (170)*.

Y Leptospira infection is a global zoonosis with significant health impact for agricultural workers and those persons whose work or recreation takes them into endemic areas

Table 4 | Evidence on injury prevention

(asterisks *) = Cochrane systematic review, CE = cost-effectiveness, E = effectiveness. Inconsistent, inconclusive, or no effective evidence can pertain to an intervention as a whole, or only certain outcomes (not) associated with it)

Interventions to prevent injuries in construction workers	E: Low-quality evidence that company-oriented safety interventions such as a multifaceted safety campaign and a multifaceted drug workplace programme can reduce non-fatal injuries among construction workers. Continuing company-oriented interventions among management and construction workers, such as a targeted safety campaign or a drug-free workplace programme, seem to have an effect in reducing injuries in the longer term	(168)* (171)
	NE: No evidence that introducing regulations for reducing fatal and non-fatal injuries are effective as such. No evidence that regionally oriented safety campaigns, training, inspections nor the introduction of occupational health services are effective at reducing non-fatal injuries in construction companies. The authors state that many interventions in practice today have not yet been evaluated and more research is needed.	(168)* (171)
Caffeine for the prevention of injuries and errors in shift workers	CE: Caffeine may be an effective intervention for improving performance in shift workers, however no trials were available to assess its effect on injuries.	(170)*
Graduated driver licensing (GDL) for reducing motor vehicle crashes among young drivers	E: Effective in reducing crash rates among young drivers, although the magnitude of the effect varies. More restrictions or higher quality based on IIHS classification appear to result in greater fatality reduction	(169)*
Post-licence driver education for the prevention of road traffic crashes	NE: No evidence that post-licence driver education is effective in preventing road traffic injuries or crashes	(172)*
Educational interventions for the prevention of eye injuries	IE: No reliable evidence that educational interventions are effective in preventing eye injuries More high-quality research is needed	(173)*

4. Ergonomic / musculoskeletal

The high prevalence of musculoskeletal disorders seems to have produced relatively more economic evaluation studies. Ten reviews in Table 5 indicate evidence for effectiveness, four for cost-effectiveness, five reviews inconsistent or inconclusive evidence, and thirteen reviews saw no evidence for the effectiveness of the studied intervention. The evidence is discussed in more detail below, and is divided into eight categories in Table 5: participatory programmes, ergonomic workstations (with or without training), education or training interventions (alone), patient handling systems, technical ergonomic measures, exercises and physical activity interventions, very broad reviews, and finally specific reviews that did not fit into the above categories.

Cost-effectiveness: Of the four reviews studying cost-effectiveness, two took a broad approach. The first of these found credible evidence (strong to limited)^Z for a wide range of ergonomic interventions across several industries and sectors (176). The second review also included multiple ergonomic programmes and made note of several cost-effective interventions (the best being a training programme and a comprehensive ergonomic programme, both to prevent occupational back pain). Moreover, they explicitly underlined that their conclusions were also applicable to developing regions (177). The third review was more specific, and indicated that introducing ceiling lifts was profitable (178). Finally, a concern of introducing ergonomic adjustments to workstations (e.g. sit-stand desks etc.) is often that it causes a loss of productivity. The fourth review showed that at least some technical ergonomic measures were effective without loss of productivity (179).



CASE STUDY Training in manual material handling

In the informal sector, which employs a large proportion of employees in low- and middle-income countries, occupational health is often a low priority and employee protection is minimal. The authors of this study focused on a wholesale market of vegetables in Calcutta (India), where most workers were at high risk of musculoskeletal or other injuries: they routinely carried loads of 100 to 120 kg (220 to 260 pounds). Three-hundred porters participated in a training programme that introduced exercise regimes to alleviate pain and discomfort at different body parts. After demonstration, workers were followed up to ensure the exercises were performed correctly. Results showed that in this setting, significant changes in physical composite scores, mental composite scores, pain scale score, and reductions in absenteeism occurred. The latter led to cost savings of \$5979 after subtracting programme costs (180).

Z Based on Slavin's best evidence approach: strong evidence amounts to minimum 3 high-quality studies agreeing on the beneficial impact, moderate evidence to 2 high-quality or 3 of medium and high-quality agreeing, limited evidence to 1 high-quality and 2 medium-quality studies agreeing on the impact. Mixed evidence means findings from medium and high-quality studies are contradictory, insufficient evidence indicates no high-quality and only one medium-quality study was found (174, 175).

Effectiveness: Evidence on the effectiveness of interventions that aim to prevent musculoskeletal disorders was observed in multiple areas, often supported by moderate or strong evidence. First, participatory programmes were supported by specific reviews as well as by some of the more broad reviews (176, 179, 181-183). Second, ergonomic workstations seem to be most effective when combined with training (176, 184), with the exception of the use of arm support with an alternative mouse (185)*. Effectiveness was less evident for several workstation adjustments without training (184, 185)*(179) (186)*(187), or for education/training alone (173, 179, 184, 187). Third, the effectiveness (and cost-effectiveness) of specific patient handling systems (176, 178, 188) and some technical ergonomic interventions (179) were both supported by one review. Next, several exercise programmes were

supported by effectiveness evidence: post-treatment exercise programmes (189)*, advice to stay active compared to advice to rest in bed (190)*, specific strengthening exercises as a part of routine practice for chronic neck pain, cervicogenic headache and radiculopathy (191)*, strengthening and endurance exercises for the cervico-scapulothoracic and shoulder (191)*, and several physical activity programmes included in a broadly scoped effectiveness review (52). One additional review found moderate evidence that multidisciplinary interventions (including organisational, technical and individual measures) are more effective than single measures (179). For other interventions there was no evidence of effectiveness or the results were inconclusive (27).

Table 5 | Evidence on ergonomic interventions by intervention type

[asterisks (*) = Cochrane systematic review, CE = cost-effectiveness, E = effectiveness, IE = inconsistent or inconclusive evidence of effectiveness, ICE = inconsistent or inconclusive evidence of cost-effectiveness, NE = no evidence for effectiveness, NCE = no evidence for cost-effectiveness. Inconsistent, inconclusive, or no effective evidence can pertain to an intervention as a whole, or only certain outcomes (not) associated with it]

FOCUS	KEY FINDINGS	REVIEW
Participatory programmes		
Participatory ergonomics programmes	E: Evidence for effectiveness	(179, 181-183)
Ergonomic workstations / training		
Ergonomic workstation adjustments combined with ergonomic training	E: Moderate evidence of effectiveness for ergonomic workstation adjustments combined with ergonomic training	(184)
	IE: Training alone on manual lifting gave inconsistent results	(184)
	NE: No evidence for effectiveness of ergonomic workstation adjustments alone	(184)
Ergonomic design and/or training for preventing work-related musculoskeletal disorders (MSD) of the upper limb and neck in adults	E: Moderate-quality evidence suggests that the use of arm support with alternative mouse may reduce the incidence of neck/shoulder MSDs, but not right upper limb MSDs	(185)*
	NE: Moderate-quality evidence suggests that the incidence of neck/shoulder and right upper limb MSDs is not reduced when comparing alternative and conventional mouse with and without arm support. Very-low- to low-quality evidence to suggest that other ergonomic interventions do not prevent work-related MSDs of the upper limb and neck. However, this conclusion was limited by the paucity and heterogeneity of available studies	(185)*
Prevention of any kind of computer-related MSDs or visual problems by means of ergonomic training, arm supports, alternate keyboards, rest breaks, screen filters	IE: Weak positive but inconsistent	(192)
Lumbar supports for prevention of low-back pain	NE: Moderate evidence that they are not any more effective than no intervention or training	(179) (186)*
Primary prevention of back pain at the workplace	NE: No evidence for the effectiveness of lumbar supports or education in the primary prevention of low back pain at the workplace.	(187)
Education / training (alone)		
Educational interventions to reduce eye injuries	IE: No reliable evidence due to poor study quality	(173)
Training on working methods in manual handling	NE: No evidence for effectiveness if it is used as the only measure to prevent low back pain	(179)

Patient handling systems		
OHS business cases (mostly considering automation and ceiling lifts)	CE: 19 out of 22 studies were profitable	(178)
Patient handling systems	E: Multicomponent systems that included a policy change, purchase of patient lifting technology and training on the new machines can reduce back pain	(188)
Technical ergonomic measures		
Technical ergonomic measures	CE: Technical ergonomic measures can reduce the workload on the back and upper limbs without the loss of productivity;	(179)
	E: Strong evidence that these measures can also reduce the occurrence of MSDs	(179)
Exercise / physical activity		
Exercises for prevention of recurrences of low-back pain	E: Moderate quality evidence that post-treatment exercise programmes can prevent recurrences of back pain	(189)*
	IE: Conflicting evidence was found for treatment exercise	(189)*
Advice to rest in bed versus advice to stay active for acute low-back pain (LBP) and sciatica	E: Moderate quality evidence shows that patients with acute LBP may experience small benefits in pain relief and functional improvement from advice to stay active compared to advice to rest in bed; patients with sciatica experience little or no difference between the two approaches. Low quality evidence suggests little or no difference between those who received advice to stay active, exercises or physiotherapy	(190)*
Exercises for mechanical neck disorders	E: Using specific strengthening exercises as a part of routine practice for chronic neck pain, cervicogenic headache and radiculopathy may be beneficial. The use of strengthening and endurance exercises for the cervico-scapulothoracic and shoulder may be beneficial in reducing pain and improving function	(191)*
	NE: When only stretching exercises were used no beneficial effects may be expected	(191)*
Primary prevention of back pain at the workplace	E: Limited evidence for the efficacy of exercise, and the effect that can be obtained is moderate Need for more high-quality research	(187)
Rest breaks combined with exercise (during the rest breaks)	NE: Moderate evidence of no effect	(192)
Other / multiple intervention types		
Workplace ergonomic interventions (including participatory ergonomics teams, mechanical patient lifts, workstation modifications, and adjustable office chairs)	CE: Credible evidence for the cost-effectiveness of ergonomic interventions in several industries and sectors Quality: Most intervention studies focus on effectiveness. Few consider their financial merit, and half of those that did had a low quality economic analysis	(176)
The cost effectiveness of occupational health interventions: preventing occupational back pain	CE: Worker training was seen as a low cost, feasible, first step towards reducing back pain or injury incidence. Using WHO criteria, engineering controls and a comprehensive ergonomic programme ^{AA} looked very cost-effective for all WHO sub-regions. Other interventions also had good value for money (based on cost-effectiveness ratio's vis à vis WHO criteria as a percentage of GDP per capita). While the training programme had a higher cost-effectiveness ratio, the ergonomic programme was much more effective.	(177)

Conservative interventions for treating work-related complaints of the arm, neck or shoulder in adults	IE: Low-quality evidence that ergonomic interventions did not decrease pain at short-term follow-up but did decrease pain at long-term follow-up. More research required	(193)*
	NE: Very low-quality evidence indicating that pain, recovery, disability and sick leave are similar after exercises when compared with no treatment, with minor intervention controls or with exercises provided as additional treatment to people with work-related complaints of the arm, neck or shoulder. Low-quality evidence that ergonomic interventions did not decrease pain at short-term follow-up but did decrease pain at long-term follow-up. More research required	(193)*
Prevention and treatment of shoulder disorders (from overhead working, heavy lifting, forceful work, and working in an awkward posture)	NE: Little evidence to suggest that either primary prevention or treatment strategies in the workplace are very effective. More high-quality cost-effectiveness research is required	(176, 194)
Pre-employment strength testing	IE: Inconclusive results - positive effects for musculoskeletal injuries and costs; no evidence for effects on non-musculoskeletal injuries	(184)
Shoe insoles	NE: Strong evidence that shoe insoles do not prevent back pain	(195)
Manual material handling advice and assistive devices to prevent back pain	NE: No significant difference in outcomes between groups who received training on proper lifting and assistive devices, and those who received no training, exercise training, or back belts. Intensity or length did not matter. Moderate quality evidence that MMH advice and training with or without assistive devices does not prevent back pain or back pain-related disability when compared to no intervention or alternative interventions	(196) (197)*
Multidisciplinary interventions including organisational, technical and personal/individual measures	E: Moderate evidence that these are better than single measures in prevention of MSDs	(179)

B. Psychosocial interventions

The searches for evidence on psychosocial interventions^{AB} resulted in twelve reviews that observed evidence for effectiveness, one (a synthesis article of 14 reviews) for cost-effectiveness, one saw inconsistent or inconclusive cost-effectiveness evidence, five reviews saw inconsistent or inconclusive effectiveness evidence and three reviews observed no evidence for the effectiveness of the studied interventions (Table 6). The rest of this section looks in more detail to the (cost-) effective interventions divided into six sections: general

reviews, participatory programmes, person-directed programmes (focusing on the individual), organisational interventions (focusing on the organisation, management, or job), interventions combining individual and organisational elements, and two other distinct interventions. Compared to the other sections in this report, the quality of the evidence seems fairly limited, as is also evident from Table 6. Due to the wide spread of low-quality evidence statements, more studies are needed to draw firm conclusions on effectiveness and cost-effectiveness.

AA The full ergonomic programme contains various components, for example, an ergonomics standard/rule review by a business owner or manager on its applicability; engineering, and administrative control measures; the use of personal protective equipment; job identification, and hazard analysis; job hazard and ergonomics education and training, not only for workers, but also for employers and evaluators carrying out job (177).

AB The searches in the psychosocial intervention section were slightly different from the other sections since a synthesis article of 14 systematic reviews on the cost effectiveness of psychosocial interventions in the workplace was identified, which selected 187 relevant studies and evaluated their cost-effectiveness where possible (198). We identified one additional review (199), and several reviews on effectiveness through the article by Burton and World Health Organization (15), and the Cochrane topical database (see methods section in the appendix).

1. Cost-effectiveness evidence

A comprehensive synthesis article of 14 reviews looked at the best available evidence of the effect of mental health interventions in the workplace on work outcomes. They found moderate evidence^{AC} for the effectiveness of workplace mental health interventions on improved workplace outcomes, such as decreased absenteeism, increased productivity or other decreased costs (e.g. healthcare costs) (198). The second cost-effectiveness review (199) indicated that the interventions they studied had mixed results on mental health and work productivity, although prevention studies scored significantly better than return-to-work studies. However, they observed a lack of economic evaluation studies and of high quality study designs (such as RCTs).

2. Effectiveness evidence

General: One review indicates that police officers benefit from psychosocial interventions, in terms of physical symptoms and psychological symptoms such as anxiety, depression, sleep problems, cynicism, anger, PTSD, marital problems and distress (200)*.

Participatory: One broadly scoped review (52) found weak evidence that a participatory method for assessing and dealing with workplace needs or deficiencies has beneficial effects. One review also saw beneficial effects of the participation of employees in planning the intervention (201).

Person-directed: Two reviews (note that (202)* is an update of (203)*) stated the interventions they studied were effective, both focusing on stress prevention in the healthcare sector. They concluded that a cognitive-behavioural approach^{AD} relaxation exercises, or a combination of both is effective, although their statements are based on low quality evidence (202)*.

Organisational: Several reviews made note of effective organisational interventions. There is evidence of an effect (on diverse outcomes) in the case of changing work schedules (202)*, job redesign (204), improving the organisational culture (205), and training employees to improve their skills or job role (206). In addition, organisational interventions were seen as effective in two subpopulations: teachers (207)* and (in case of changing the shift system) police officers (206). Others have noted that there are few studies examining organisation level interventions (27).

Individual & organisational: There is evidence for the effectiveness of combining individual and organisational approaches to reduce workplace stress (201, 208) and bullying behaviour (209)*. However, more high-quality research is required.

AC Moderate evidence was defined as a minimum of three high-quality reviews with moderate evidence and 60%–74% of reviews with effects in a positive direction. Ten out of fourteen reviews (71%) had effects in a positive direction (198).

AD "Cognitive-behavioural techniques work by providing new ways to feel, think and act in stressful situations" (202).

CASE STUDY**Comprehensive mental health prevention in Japan**

To reduce the significant social costs of mental disorders in Japan, the Japanese government developed a guideline that promotes comprehensive mental health programmes. It advises to implement aspects of primary prevention (health education and workplace reviews), secondary prevention (mental health check-ups, interviewing overworked employees, and the introduction of hospital services for employees) and tertiary prevention (periodic interviews with occupational doctors and nurses, information exchanges between caretakers, and job transfer assistance). The study used a questionnaire among 11 employers (or their occupational health staff) to assess the effectiveness of implementing these guidelines. On average, implementation rates were 66% for primary, 51% for secondary, and 60% for tertiary programmes. Taking both effects on absenteeism and presenteeism into account, return on investment for companies ranged between 0.27 and 16.82, with seven out of 11 companies receiving net benefits from the mental health programmes (210).

[ROI = (gain from investment – cost of investment) / cost of investment:
an ROI < 1 means benefits were smaller than costs]

In addition, the evidence synthesis by Wagner et al (198) and a comprehensive report (201) on the topic, made note of several specific effective programmes, as well as success factors for designing interventions:

- programmes incorporating both mental and physical health interventions (based on one study in (211) and 19 studies in (212)),
- multicomponent mental health and/or psychosocial interventions (one study in (211), 28 studies in (213))
- (gradual) exposure in vivo containing interventions for particular anxiety disorders – such as obsessive compulsive disorder (OCD), post-traumatic stress disorder (PTSD) and phobias – (seven studies in (214)).
- high-intensity mental health intervention, access to clinical treatment, and support in navigating disability management programmes (eight studies in (214). implementation and evaluation of changes (201)
- management supporting employees through effective communication (201)

Table 6 | Evidence on psychosocial interventions

[asterisks (*) = Cochrane systematic review, CE = cost-effectiveness, E = effectiveness, IE = inconsistent or inconclusive evidence of effectiveness, ICE = inconsistent or inconclusive evidence of cost-effectiveness, NE = no evidence for effectiveness, NCE = no evidence for cost-effectiveness. Inconsistent, inconclusive, or no effective evidence can pertain to an intervention as a whole, or only certain outcomes (not) associated with it]

FOCUS	KEY FINDINGS	REVIEW
General		
Synthesis of systematic reviews of mental health interventions in the workplace	CE: Moderate evidence for the effectiveness of workplace mental health interventions on improved workplace outcomes. Quality: the diversity of the literature surrounding mental health interventions (from pamphlets to complex multi-component interventions) complicates drawing broad conclusions on cost-effectiveness. Most studies used mental health functioning as outcome, without making the link to economic outcomes	(198)
Psychosocial interventions for prevention of psychological disorders in law enforcement officers	E: Evidence suggests that police officers benefit from psychosocial interventions, in terms of physical symptoms and psychological symptoms such as anxiety, depression, sleep problems, cynicism, anger, PTSD, marital problems and distress Quality: conclusions based on individual small and low-quality trials with minimal data. More high-quality research is needed	(200)*
Prevention or treatment of mental health	ICE: Prevention or treatment studies: 4 cost-beneficial, RTW studies: 5 not cost-beneficial, one cost-effective Quality: On average, 65% of the CHEC-list criteria were met, 45% for the prevention studies, 71% for the return to work interventions	(199)
Participatory		
Health Circles (Germany)	E: Weak but positive evidence that a formalized participatory method for assessing and dealing with workplace needs or deficiencies reduces stress, and benefits work satisfaction and health risk factors	(52)
Person-directed		
Person-directed stress management programmes in healthcare workers	E: Low-quality evidence that cognitive behavioural therapy and mental and physical relaxation reduce stress more than no intervention (but not more than alternative interventions)	(202)* (203)*
Individual stress management programmes	IE: Varying effectiveness on perception of stress and mental well-being, with cognitive-behavioural approaches the most successful. However, they tend to be short-lived and to have little effect on productivity or organisational measurements	(214)
Computer-based versus in-person interventions for preventing and reducing stress in workers	IE: Very low-quality evidence with conflicting results when comparing the effectiveness of computer-based stress management interventions with in-person stress management interventions in employees	(217)*
Organisational		
Organisational stress management programmes in healthcare workers	E: Low-quality evidence that changing work schedules may lead to a reduction of stress	(202)*
Stress reduction by (organisational) job redesign	E: Effective in reducing workplace stress	(204)
Organisational culture	E: "Particularly effective in improving musculoskeletal health" (15)	(205)

Organisational interventions for improving well-being and reducing work-related stress in teachers	E: Low-quality evidence that organisational interventions lead to improvements in teacher well-being and retention rates More high-quality research is needed	(207)*
Organisational intervention studies to reduce sources of stress	IE: No impact, possibly because of very small number of studies	(52)
Organisational participatory interventions to improve mental well-being	IE: Insufficient evidence of good quality	(206)
Supervisory training	IE: Insufficient evidence to assess impact on mental well-being of subordinates	(206)
Changing the shift system of police officers	E: Changes from 7-day consecutive shifts to the 35-day Ottawa system had a positive impact on mental well-being	(206)
Psychosocial intervention training of employees to improve skills or job role	E: Positive impact on burnout in the short term	(206)
Organisational-level interventions	E: Limited evidence (based on 8 studies) that organisational-level interventions reduce stress, psychological symptoms, or absenteeism in the workplace	(218)
Combining individual & organisational elements		
Combination of individual and organisational approaches to workplace stress	E: <i>"The most effective"</i> (15)	(201)
Combination of personal stress management with organisational efforts to increase participation in decision-making and problem-solving, increase social support, and improved organisational communication	E: Effective in preventing/improving psychological ill-health	(208)
Interventions for prevention of bullying in the workplace	E: Very low-quality evidence that organisational and individual interventions may prevent bullying behaviours in the workplace. More high-quality research is needed	(209)*
Other		
Short psychological debriefing for the management of distress after trauma to prevent post-traumatic stress disorder (PTSD)	NE: No evidence that a single session is useful, and in fact may actually increase the incidence of depression and PTSD	(219)*
Job stress management training	NE: No evidence for an effect on upper extremity MSD outcomes	(201, 220)

C. Return to work interventions

The evidence and conclusions on return to work interventions are synthesized by focusing on the targeted population/ the reason for absence: musculoskeletal problems or disability, a disease, and mental health. Overall, seven reviews stated evidence for cost-effectiveness, thirteen reviews for effectiveness, thirteen noted inconsistent or inconclusive evidence, and four reviews saw no evidence for the effectiveness of the studied interventions.

General effectiveness: Two reviews assessed the overall effectiveness of return-to-work interventions, regardless of the population, on preventing work disability and improving return to work. One review noted positive evidence regarding reducing time to first RTW, and cumulative duration of sickness absence, although not for all subpopulations (e.g. workers with mental health problems or cancer) (221)*. The other review found no evidence for effectiveness on a wide range of outcomes, but due to the quality of the included studies, new research is likely to change results (222)*.

General cost-effectiveness: Several intervention components and features of disability management interventions were seen as cost-effective (223), regardless of the targeted population, and this holds a fortiori for disability and return to work programmes that use a participatory approach (184).

1. Musculoskeletal

Cost-effectiveness: Five reviews assessed the cost-effectiveness of return-to-work interventions in case of musculoskeletal health problems. **Tompa, de Oliveira (223)** observed strong evidence on cost-effectiveness of multi-sector disability management, moderate evidence for interventions with an educational component (e.g.

back school), physiotherapy, vocational rehabilitation,^{AE} work accommodation offers, health care provider and work contacts, early contact with worker by workplace, ergonomic work visits and interventions with a return-to-work coordinator, and limited evidence for interventions with a behavioural component. Three out of four disability management programmes identified by **Lerner et al. (225)**, mostly concerning care and case management, had favourable results on claims and lost time. However, none calculated programme costs or cost-effectiveness. An additional intervention aimed at reducing low back pain (through worksite-based acupuncture, relaxation techniques, advice, and a booklet) also had positive results on cost-effectiveness. Two out of four studies identified by Carroll were cost-beneficial (BCR^{AF} of 7.7, and savings of €84 181 - €208 750 per female on sick leave), one stated a cost per RTW day gained of €23, and one did not assess costs but noted significant cost savings (226). **Franche et al.** noticed that interventions, which include early contact with worker by workplace, ergonomic work site visits, and presence of a RTW coordinator reduce costs associated with work disability duration (227). One review focusing on assisting people with persistent musculoskeletal pain stated that **multilevel-focused interventions** may provide some cost benefit compared to more standard forms of medical centred care (228).

Effectiveness: Early intervention, as well as interventions involving employees, health practitioners and employers working together to implement work modifications for the absentee (in case of musculoskeletal health problems), were more consistently effective than other interventions (226). Additionally, modified work can help early return to work (178).

AE Vocational rehabilitation is "a process that enables persons with functional, psychological, developmental, cognitive and emotional impairments or health disabilities to overcome barriers to accessing, maintaining or returning to employment or other occupation" (224)

AF BCR = benefit-cost-ratio = benefits / costs. It is different from the return on investment (ROI), which can be defined as (benefits - costs) / costs, although definitions can differ.

Finally, to return employees to work after experiencing back pain, there is (effectiveness) evidence that

- it is important for patients to stay active and return to ordinary activities as early as possible (15, 179)
- a combination of optimal clinical management, a rehabilitation programme and workplace interventions is more effective than single elements alone (15, 179)
- taking a multidisciplinary approach offers the most promising results (15, 179)
- temporarily modified work is an effective return to work intervention if embedded in good occupational management (15, 179)
- some evidence supports the effectiveness of exercise therapy, back schools and behavioural treatment (15, 179)
- in the short-term, operant therapy is more effective than waiting list and behavioural therapy is more effective than usual care for pain relief in chronic low-back pain (229)*
- back schools, in an occupational setting, reduce pain, and improve function and return-to-work status, in the short and intermediate-term, compared to exercises, manipulation, myofascial therapy, advice, placebo or waiting list controls, for patients with chronic and recurrent low back-pain (LBP) (230)*
- Patients with chronic LBP receiving multidisciplinary biopsychosocial rehabilitation (MBR) are likely to experience less pain and disability than those receiving usual care or a physical treatment, MBR has a positive influence on work status compared to physical treatment, and on average, people with subacute LBP who receive MBR will do better than if they receive usual care (231)*(232)*.

2. Disease management

Cost-effectiveness: Six out of eight disease management programmes identified by Lerner et al. had favourable cost-effectiveness results, although there was little standardization in programme outcome metrics (reduced claims costs, absences, at-work performance, ...) (225). The programmes focused on reducing the productivity impacts at work of asthma (n=2), diabetes (n=1), coronary artery disease (n=1), migraine (n=1), and on low back pain (previously discussed).

Effectiveness: In addition, other reviews indicated that multidisciplinary interventions enhance the RTW of patients with cancer (233)*, and that job loss prevention interventions have an effect on job loss, work absenteeism and work functioning in workers with inflammatory arthritis (234)*.

3. Mental health

Cost-effectiveness: One Cochrane review of 23 studies (14 with high risk of bias and 9 with low risk of bias) aiming to improve return to work among depressed people saw moderate quality evidence (3 studies) that a work-directed intervention added to a clinical intervention reduced sickness absence compared to a clinical intervention alone, and moderate quality evidence (based on a single study) that enhancing the clinical care in addition to regular work-directed care was not more effective than work-directed care alone (235). However, another review (once again with a limited number of studies) found no cost-beneficial interventions in 5 out of 6 studies RTW studies (199).

Effectiveness: Evidence indicated that supported employment^{AH} can be effective (236)*, and can be more effective than pre-vocational training in helping severely mentally ill people to obtain competitive employment (237)*. Finally, supported employment and augmented

supported employment (combining supported employment with other prevocational or psychiatric interventions) were seen to be effective for people with severe mental illness in terms of obtaining and maintaining employment, without increasing the risk of adverse events (238)*.

4. Conclusion

Overall, as indicated in Table 7, evidence indicates that early assessment and rehabilitation, including work and workplace adjustments seems to be a cost-effective strategy (178), and multi-component programmes appear to be the most successful and cost-effective (27, 226). Finally, other authors have observed strong evidence for the impact of managing long-term sickness absence (27).

Table 7 | Evidence on return to work (RTW)

[asterisks (*) = Cochrane systematic review, CE = cost-effectiveness, E = effectiveness, IE = inconsistent or inconclusive evidence of effectiveness, ICE = inconsistent or inconclusive evidence of cost-effectiveness, NE = no evidence for effectiveness, NCE = no evidence for cost-effectiveness. Inconsistent, inconclusive, or no effective evidence can pertain to an intervention as a whole, or only certain outcomes (not) associated with it]

FOCUS	KEY FINDINGS	REVIEW
General		
Workplace interventions to prevent work disability in workers on sick leave	E: Moderate-quality evidence that workplace interventions reduce time to first RTW High-quality evidence that workplace interventions reduce cumulative duration of sickness absence. Very low-quality evidence that workplace interventions reduce time to lasting RTW. E in subpopulations: Moderate-quality evidence to support workplace interventions for workers with musculoskeletal disorders Quality: low quality of evidence for workers with mental health problems and cancer	(221)*
Workplace interventions to prevent work disability in workers on sick leave	NE: No evidence of a considerable effect of workplace interventions on time to RTW in workers with mental health problems or cancer. Moderate-quality evidence (one study) that workplace interventions increase recurrences of sick leave	(221)*
Return-to-work coordination programmes for improving return to work in workers on sick leave	NE: For workers on sick leave for at least four weeks, no significant differences for a large group of outcomes was found when comparing return-to-work coordination programmes with usual care (time to return to work, cumulative sickness absence, the proportion of participants at work at end of the follow-up or the proportion of participants who had ever returned to work at short-term, long-term or very long-term follow-up), and only small effects (smaller than minimally important different effect) on patient-reported outcomes, were found. Quality: The quality of the evidence ranged from very low to moderate across all outcomes. New research is likely to change the results	(222)*
Disability management programmes	ICE: 3 favourable, 1 unfavourable effect on economic outcomes. Intervention costs were not calculated and no (full) CE analysis was made. Quality: No measurement of productivity after return to work (despite risk of impaired functioning upon return) and few adjustments for potential confounders despite vulnerability to historical bias and confounding	(225)
	CE: Credible evidence supporting the financial benefits of disability management interventions for one industry cluster and several intervention components and features.	(223)
Disability management/ return to work programmes using a participatory approach that includes a health care provider, supervisors and workers, and workers' compensation carriers	E: Strong evidence of effectiveness	(184)
	CE: Strong evidence on workers' compensation cost reductions	(184)

Musculoskeletal		
RTW interventions provided at the workplace to workers with work disability associated with musculoskeletal or other pain-related conditions	E: Strong evidence that work disability duration is significantly reduced by work accommodation offers and contact between healthcare provider and workplace; moderate evidence that it is reduced by interventions which include early contact with worker by workplace, ergonomic work site visits, and presence of a RTW coordinator	(227)
	CE: Moderate evidence that interventions which include early contact with worker by workplace, ergonomic work site visits, and presence of a RTW coordinator reduce costs associated with work disability duration. Evidence for sustainability of these effects was insufficient or limited	
Return to work among employees with back pain on long-term sick leave	CE: 4 studies evaluated cost-effectiveness. Interventions involving employees, health practitioners and employers working together to implement work modifications for the absentee, were more consistently effective than other interventions, as well as early intervention. Quality: The majority of trials were of good or moderate quality	(226, 227)
Behavioural treatment for chronic low-back pain (CLBP)	E: Moderate quality evidence that in the short-term, operant therapy is more effective than waiting list and behavioural therapy is more effective than usual care for pain relief, but no specific type of behavioural therapy is more effective than another	(229)*
	NE: In the intermediate- to long-term, there is little or no difference between behavioural therapy and group exercises for pain or depressive symptoms	(229)*
Back schools for non-specific low-back pain	E: Moderate evidence suggesting that back schools, in an occupational setting, reduce pain, and improve function and return-to-work status, in the short and intermediate-term, compared to exercises, manipulation, myofascial therapy, advice, placebo or waiting list controls, for patients with chronic and recurrent LBP	(230)*
Multidisciplinary biopsychosocial rehabilitation (MBR) for chronic low back pain (LBP)	E: Patients with chronic LBP receiving MBR are likely to experience less pain and disability than those receiving usual care or a physical treatment. MBR also has a positive influence on work status compared to physical treatment. Low to very low-quality evidence that, on average, people with subacute LBP who receive MBR will do better than if they receive usual care, but it is not clear whether they do better than people who receive some other type of treatment	(231)* (232)*
Individually versus multilevel focused workplace interventions aimed at assisting people with persistent musculoskeletal pain to remain productively employed	ICE: One study of low quality (small sample size) indicates that individually focused interventions may make little or no difference to cost benefit, two studies of moderate quality indicate multilevel focused interventions will probably increase cost benefit. The limited number of studies at both an individual and multilevel focus that address workplace interventions and the low quality of the available studies make it not possible to conclude which focus—individual or multilevel—is preferable	(228, 231)
Vocational rehabilitation ^{AH} for enhancing return-to-work in workers with traumatic upper limb injuries	IE: No high-level evidence to support or refute the efficacy of vocational rehabilitation in enhancing RTW in workers with traumatic upper limb injuries	(224)*
Multidisciplinary rehabilitation for fibromyalgia and musculoskeletal pain in working age adults	IE: Little scientific evidence for the effectiveness of multidisciplinary rehabilitation for these musculoskeletal disorders. Need for more high-quality research	(239)*
Multidisciplinary biopsychosocial rehabilitation for neck and shoulder pain among working age adults	IE: Little scientific evidence for the effectiveness of multidisciplinary biopsychosocial rehabilitation compared with other rehabilitation facilities for neck and shoulder pain	(240)*

Physical conditioning as part of a return to work strategy to reduce sickness absence for workers with back pain	IE: Uncertain effectiveness of physical conditioning as part of a return to work strategy in reducing sick leave for workers with back pain, compared to usual care or exercise therapy	(241)*
Assistive devices, hip precautions, environmental modifications and training to prevent dislocation and improve function after total hip arthroplasty (THA)	IE: Very low-quality evidence leads to uncertainty whether hip precautions with or without the addition of equipment and functional restrictions are effective in preventing dislocation and improving outcomes after THA Insufficient evidence to support or refute the adoption of a postoperative community rehabilitation programme consisting of functional reintegration and education compared to conventional rehabilitation strategies based on functional outcomes More high-quality research is needed	(242)*
Disease management		
Interventions to enhance return-to-work for cancer patients	E: Moderate quality evidence that multidisciplinary interventions enhance the RTW of patients with cancer.	(233)*
Non-pharmacological interventions for preventing job loss in workers with inflammatory arthritis	E: Very low-quality evidence overall for job loss prevention interventions having an effect on job loss, work absenteeism and work functioning in workers with inflammatory arthritis	(234)*
Effectiveness of vocational rehabilitation (VR) ³¹ intervention on the return to work and employment of persons with multiple sclerosis (pwMS)	IE: Inconclusive evidence to support VR for pwMS More high-quality research needed	(243)*
Disease management	CE: 6 out of 8 had favourable results, focus ranged from asthma (2), diabetes (1), coronary artery disease (1), low back pain (1) to migraine (1)	(225, 233)
Interventions for improving employment outcomes for workers with HIV	IE: Very low-quality evidence that antiretroviral therapy (ART) interventions may improve employment outcomes for HIV+ persons. No evidence of an intervention effect for vocational interventions Need for more high-quality research	(244)*
Mental health		
Vocational rehabilitation ³¹ for people with severe mental illness	E: Supported employment is more effective than Pre-vocational Training in helping severely mentally ill people to obtain competitive employment	(237)*
Supported employment for adults with severe mental illness	E: Limited evidence that supported employment is effective in improving a number of vocational outcomes relevant to people with severe mental illness Quality: There appears to exist some overall risk of bias in terms of the quality of individual studies	(236)*
Interventions to improve return to work in depressed people	CE: Moderate quality evidence that adding a work-directed intervention to a clinical intervention reduced the number of days on sick leave compared to a clinical intervention alone. Moderate quality evidence that enhancing primary or occupational care with cognitive behavioural therapy reduced sick leave compared to the usual care. Structured telephone outreach and care management that included medication reduced sickness absence compared to usual care	(235)*

	IE: Enhancing primary care with a quality improvement programme did not have a considerable effect on sickness absence. No evidence of a difference in effect on sickness absence of one antidepressant medication compared to another	(235)*
Interventions for obtaining and maintaining employment in adults with severe mental illness, a network meta-analysis	E: Moderate- to low-quality evidence that supported employment and augmented supported employment were effective for people with severe mental illness in terms of obtaining and maintaining employment, without increasing the risk of adverse events	(238)*
Interventions to facilitate return to work in adults with adjustment disorders	IE: Moderate-quality evidence that cognitive behavioural therapy (CBT) did not significantly reduce time until partial RTW and low-quality evidence that it did not significantly reduce time to full RTW compared with no treatment. Moderate-quality evidence that PST significantly enhanced partial RTW at one-year follow-up compared to non-guideline based care but did not significantly enhance time to full RTW at one-year follow-up	(245)*
Mental health interventions aimed at return to work	ICE: 5 not cost-beneficial, one cost-effective Quality: On average, 65% of the CHEC-list criteria were met, 45% for the prevention studies, 71% for the return to work interventions	(199)

D. Health screening

Overall, limited evidence is available on the effectiveness of (general) periodic health screenings in an occupational setting, and there is especially a lack of evidence on the economic consequences to employees, employers and society in terms of direct healthcare usage and productivity loss. The need for studies with a stronger and better design, and including economic indicators, is therefore significant. The conclusions of these reviews should also be seen in their context: the effectiveness of health screening depends on the prevalence of the disease, which might be higher in developing countries (where workers often face more risks) and screening thus has higher potential. However, there seems to be some consensus on the (cost-) effectiveness of biometric screening^{AI} (247-249), especially when these are combined with well-designed workplace wellness programmes (250).

A thorough investigation of the **effectiveness of (general) health screenings** by the Cochrane collaboration has found 14 trials of sufficient quality (251, 252), including one that assessed screening at the workplace. Compared with usual care, the provision of health checks was not associated with lower rates of all-cause mortality, mortality from cardiovascular disease, or mortality from cancer. On the other hand, health checks may be associated with adverse consequences such as false reassurance or overuse of medical care. However, we note that only one intervention was located at the workplace, most trials were old, morbidity was infrequently reported, and economic consequences were only assessed twice (and moreover in the 1960s) (253). The intervention at the workplace was (although statistically insignificant) in favour of health checks.

More specific screening interventions often had little or no high-quality research, such as indicated by a Cochrane review on vision screening of older drivers (254), a review on tuberculosis screening of healthcare workers (255), or on tomography screening for lung cancer (256).

AI Biometric screening is defined by the Centers of Disease Control and Prevention as "the measurement of physical characteristics such as height, weight, body mass index, blood pressure, blood cholesterol, blood glucose, and aerobic fitness tests that can be taken at the worksite and used as part of a workplace health assessment to benchmark and evaluate changes in employee health status over time." (246).



CASE STUDY

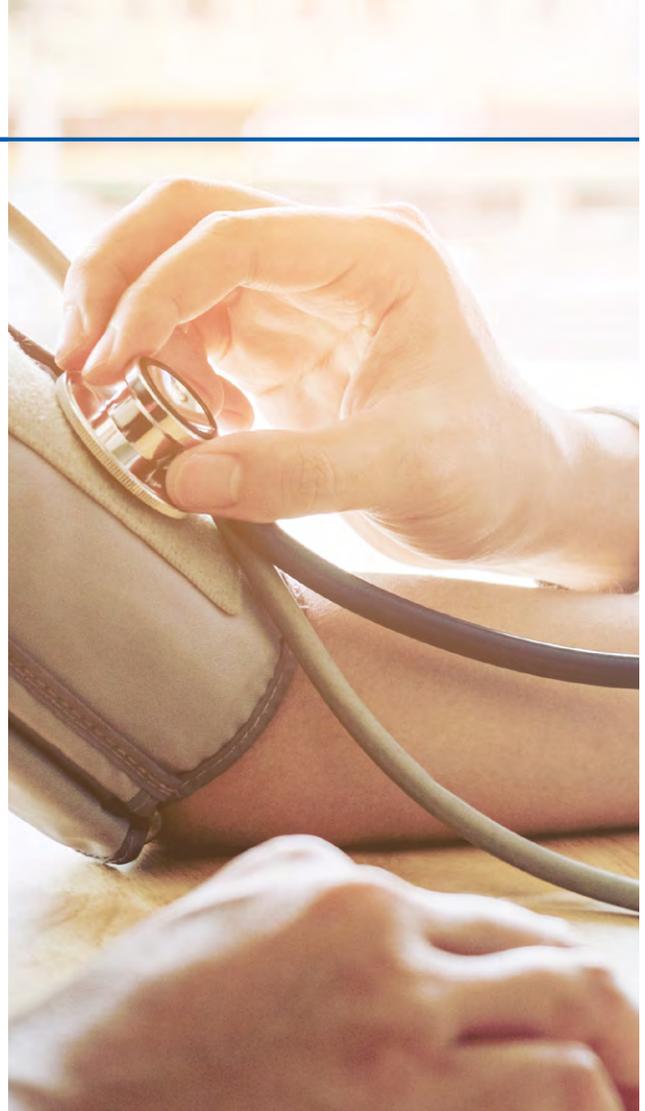
General health screening by the general practitioner

Since valid tests are available in occupational asthma, this area holds a stronger potential to demonstrate the benefits of health surveillance. While few studies are available on the topic (257), those that exist indicate that early detection of cases by periodic health surveillance had some positive impact upon outcomes (27, 258, 259).

A Cochrane systematic review of **pre-employment examinations** for preventing injury, disease and sick leave in workers, found that health examinations that focus on health risks of particular jobs might be effective, as well as adequately dealing with potential health risks by changing work tasks or physical fitness training. However, all studies were judged to be of low quality. In addition, they state that pre-employment examinations may result in an increase of rejecting job applicants in six out of seven studies (260).

Good studies on the effects of health screening are particularly difficult to carry out in the occupational health setting. Taking a public health perspective, however, an article by Hackl, Halla (261), studied the effect of a general health-screening programme by the general practitioner on individuals' health status and health-care cost (by means of a matched insurant-general practitioner panel data set). They found that while in the short-run participation in health screening increased inpatient and outpatient health-care costs (up to 2 years after treatment), it saved costs in the outpatient sector in the medium run. The authors do not recommend general screenings but suggest more targeted screening.

There is some consensus that conducting **biometric screenings** in the workplace can detect established risk factors early on, thereby preventing the development of non-communicable diseases, or managing a diagnosed condition and preventing subsequent events (247-249). If targeted at higher risk individuals, this detection may be even more effective and result in higher ROI (246, 262-266). These biometric screenings are often conducted yearly or two-yearly, but there is no strong evidence to justify this frequency (250). Several studies indicate that employee health screening together with a well-designed comprehensive health and wellness programme can be cost-beneficial (250). On the other hand, a number of randomized, controlled trials (267, 268) found that [biometric] screenings alone *“offered little ROI benefit, whereas an assessment followed by behavioural counselling and incentives achieved favourable cost savings”* (246).



CASE STUDY

Preventive health checks

Rasmussen et al. (269) investigated whether preventive health checks and health discussions are cost effective in a randomized trial with 6 years follow-up, where patients were offered broad screening including cardiovascular risk and a personal letter including screening results and advice on healthy living. One group could contact their family physician for a normal consultation, the other was given fixed appointments for health consultations. Both intervention groups had better life expectancy than the control group, and the effect of the second group (fixed appointments) was larger. Unfortunately, there were no statistically significant differences in direct or total costs.

E. Health promotion

Health promotion at work can encompass a broad range of interventions, from physical activity to nutrition, smoking cessation or reducing alcohol use. Usually, some element is present in the programme that aims to change elements of the “lifestyle” or behaviour of employees. Across all types of interventions, nine reviews stated evidence for cost-effectiveness, sixteen for effectiveness, seven noted inconsistent or inconclusive cost-effectiveness evidence, seven inconsistent or inconclusive effectiveness evidence, two reviews saw no evidence for the cost-effectiveness of the studied intervention, and seven saw no evidence for the effectiveness of the studied interventions. Several reviews noted a lack of quality and standardisation (27, 270-272), and some even noted an inverse relation between study quality and effect on economic outcomes (27, 273).

1. General and comprehensive interventions

Cost-effectiveness: Five reviews examined the overall cost-effectiveness of workplace health promotion programmes, by selecting several studies that focus on different topics (such as physical activity, smoking, etc.). One of these reviews was previously mentioned in the introduction, and noted that on average medical costs fall by about \$3.27 for every dollar spent on health promotion (labelled “wellness programmes” by the authors), while absenteeism costs fall by about \$2.73 for every dollar spent (49). The other reviews and reports also found evidence for overall positive ROI (48, 273), cost reductions (in sick leave, health plan costs, workers’ compensation costs, turnover), and improved reputation and productivity (22, 274).

Three reviews (note that (275) is an update of (276)) examined the cost-effectiveness of comprehensive health promotion programmes, which combine several components in one intervention. They found

that the majority of programmes had positive effects on economic outcomes (275, 276) and a positive ROI (277). However, while positive changes in study quality were noted over time, there was still substantial room for improvement.

Effectiveness: Six reviews discussed the general effectiveness of health promotion. Two noted positive health effects in small business (274, 278), two saw effectiveness evidence on a broad range of lifestyle outcomes (smoking, weight, cholesterol, physical activity) (22, 183), and two found improved mental well-being in the participants (183, 206).

2. Physical activity

Nicholson et al. conclude on the basis of three reviews that the effectiveness of workplace physical activity programmes to increase exercise levels is limited or moderate (27). Activity permissive workstations in office workers are effective and do not seem to have negative short-term productivity costs, but long-term productivity effects were not assessed (279). In addition, sick leave is not reduced, and there is inconsistent evidence of the impact on productivity (27, 280). Lastly, there seems to be an inverse relation between study quality and effect on economic outcomes (27). An overall need for quality improvement has been noted (281).

3. Nutrition / dietary interventions

Similar to physical activity programmes, the quantity and quality of research must improve before firm conclusions can be drawn regarding cost-effectiveness of nutrition and dietary interventions (281, 282). Positive effects were noted upon absenteeism and presenteeism, but the size of these effects was not compared to the costs of the programme (282).

More specifically, workplace weight management programmes have unclear evidence of effectiveness, and a lack of evidence for long-term economic effects



CASE STUDY

Health promotion at Johnson & Johnson

(27). Interventions which targeted fruit and vegetable intake were most likely to be successful in worksites according to one review (283).

4. Smoking cessation and alcohol interventions

While the financial burden of tobacco use for the employer has been demonstrated (284), there is low strength of evidence that individual workplace smoking cessation interventions can be effective, and when they are it is under certain circumstances (smokers must be willing to quit), and the effect decreases over time (27). However, future research might change these conclusions. Smoking bans and group smoking programmes seem to have the highest potential. There is insufficient evidence available on cost-effectiveness to draw conclusions on economic variables. The same holds for workplace alcohol interventions, although one review indicated that interventions for problem drinking appear to reduce injuries and their antecedents (e.g. falls, motor vehicle crashes, suicide attempts) (285)*.

The Johnson & Johnson program “Live for Life” was introduced in 1979. Today, it covers a wide range of intervention features: physical activity (on-site fitness centres, reimbursement for exercise expenditures, pedometers, seasonal fitness challenges), nutrition (healthy cafeteria choices, Weight Watchers membership, online weight management tools), lifestyle management (health coaching for blood pressure management, tobacco cessation, blood lipid control), and chronic disease management. Compared to similar groups (through propensity-score matching), beneficial effects were observed on obesity, blood pressure, cholesterol, tobacco use, physical inactivity, and nutrition. In 2009, \$565 was saved on average per employee, equivalent to a ROI of 1.88-3.92, by reducing medical costs to the company (286).

5. Key elements for intervention design

Three reviews (287-289) identified the following key elements of successful workplace health promotion:

- Having clear goals and objectives, links to business objectives, strong management support, employee involvement at all stages, supportive environments, adapting the programme to social norms (287)
- Increasing participation rates by using a participatory process to involve workers and their representatives in the preparation and execution of the measures (288)
- Health promotion programmes that utilize a “stages of change” approach to individualize the intervention to the individual employee’s characteristics are more effective (288)
- Promising practices for success in health promotion (289):
 - integrating health promotion programmes into the organisation’s operations
 - simultaneously addressing individual, environmental, policy and cultural factors affecting health and productivity
 - targeting several health issues
 - tailoring programmes to address specific needs
 - attaining high participation
 - rigorously evaluating programmes
 - communicating successful outcomes to key stakeholders.

Table 8 | Reviews on health promotion

[asterisks (*) = Cochrane systematic review, CE = cost-effectiveness, E = effectiveness, IE = inconsistent or inconclusive evidence of effectiveness, ICE = inconsistent or inconclusive evidence of cost-effectiveness, NE = no evidence for effectiveness, NCE = no evidence for cost-effectiveness. Inconsistent, inconclusive, or no effective evidence can pertain to an intervention as a whole, or only certain outcomes (not) associated with it]

FOCUS	KEY FINDINGS	REVIEW
General		
Workplace wellness programmes with a non-participating control group.	90% of interventions were implemented in large firms. Most common foci of programmes were obesity and smoking. CE: Medical costs fall by about \$3.27 for every dollar spent on wellness programmes, absenteeism costs fall by about \$2.73 for every dollar spent	(49)
Relation between study quality and ROI in health promotion programmes	CE: Overall weighted ROI based on meta-analysis was positive (1.38-1.39). Quality: An inverse relation between ROI and study quality was found. Quality of studies improved over time	(49, 273)
Meta-evaluation of worksite health promotion	CE: Strong evidence for average reduction in sick leave, health plan costs and workers' compensation costs of around 25%. Quality: General lack of standardization in the methodology	(273, 278)
Peer-reviewed studies of worksite health promotion in small businesses	CE: Not assessed E: Positive health effects Quality: limited high-quality research, only 2 of 19 studies were of sufficient quality	(274, 278)
Workplace wellness	CE: Positive impact on sickness absence, turnover, accidents & injuries, employee satisfaction, resource allocation, company reputation, productivity, health, insurance claims and competitiveness & profitability. Quality: Not explicitly assessed	(22, 274)
Work-related health promotion programmes	E: Evidence work programmes can reduce smoking behaviour, control weight (in the short term), improve attitude towards nutrition, lower blood cholesterol, increase physical activity (all these were effective among the participants, not necessarily the workforce as a whole)	(22, 183)
Web based health promotion and lifestyle training packages	E: Can improve mental well-being as measured using non-standard questionnaire at baseline and at 6 months follow-up	(183, 206)
Impact of worksite wellness on health and financial outcomes, effect of incentives of participation among studies with comparison groups	ICE: Insufficient evidence for effects on absenteeism, mixed results for other financial effects IE: Mixed evidence on substance use and physiologic markers Quality: lack of rigorous evaluation designs and effect of incentives. More positive effects in observational studies (3/4) than in RCTs (1/2)	(206, 290)
USA studies of health promotion, disease prevention and wellness programme, including fitness programmes, employee assistance programmes, and worksite medical clinics	ICE: Evidence regarding economic impact is limited and inconsistent. Quality: Higher-quality research is needed to demonstrate the value of specific programmes. Little standardisation (e.g. in outcome metrics). 10 of 44 studies were of sufficient quality, only 3 analysed direct & indirect costs	(225)
Workplace wellness programmes (RCTs only) in Europe	NCE: Economic impact was mostly negative (not cost saving or more costly and more effective) Quality: Methodological limitations in RCTs (blinding, selection bias, small sample sizes, presenteeism was not taken up) may have influenced results, non-RCTs and non-blinded RCTs may have a high probability of bias	(291)

Comprehensive		
Comprehensive health promotion and disease management programmes ^{AJ}	CE: The vast majority indicated positive economic outcomes Quality: quality of research and amount of RCTs improved over time, but caveats and limitations persist on design, participation, attrition, selection, duration, follow-up, publication bias and heterogeneity	(275, 276)
Comprehensive worksite-based population health management programmes (for all risk types)	CE: Positive ROI, but lower than older studies. Includes only peer-reviewed studies of direct health care cost impact from programmes implemented in the USA Quality: paucity of rigorous population health management research - only 5 studies on 30 were of high enough quality for inclusion	(277)
Physical activity		
Work-related exercise programmes	E: Evidence that they increase physical activities of employees, prevent MSDs, and decrease fatigue and exhaustion. Especially effective when scientific behaviour change theory is incorporated, and when sports facilities are provided	(52)
	E: Effective in reducing workplace injuries	(184)
Health promotion programmes targeting physical inactivity and diet	E: Can be effective in improving health related outcomes such as obesity, diabetes and cardiovascular risk factors	(52, 287)
Comprehensive programme to increase physical activity that includes individual counselling, health promotion education and fitness facilities	E: More effective than single-focus programmes	(184, 292)
Multicomponent workplace interventions to improve diet and exercise	E: Effective when they provide healthy food and beverages at the workplace; provide space for fitness or encourage stair use; involve the family; and provide individual behaviour change strategies	(287, 293)
Reducing sitting at work	E: Very low to low quality evidence that sit-stand desks may decrease workplace sitting between thirty minutes to two hours per day without having adverse effects at the short or medium term.	(294)*
Activity enhancement and nutrition programmes	ICE: Absenteeism effects were positive in NRS, but negative in RCTs	(293, 295)
	Quality: Substantial need for improvement in methodological quality, 50% of the studies fulfilled 11 of the 19 CHEC-list items (a standardised quality assessment tool), handling uncertainty should receive more attention	(281, 294)
Onsite workplace health-enhancing physical activity	ICE: Consistent evidence that sick leave is not reduced, inconsistent impact on productivity Quality: Lack of consistency among studies, 3 of 8 studies were of high quality, the other 5 had moderate risk of bias	(280)
Pedometer	IE: Limited and low-quality data providing insufficient evidence to assess the effectiveness of pedometer interventions in the workplace for increasing physical activity and improving subsequent health outcomes	(296)*
Reducing sitting at work	IE: No evidence on the effects of sit-stand desks in the long term. No considerable or inconsistent effects of other interventions such as changing work organisation or information and counselling. More high-quality research is needed	(294)*
Activity permissive workstations in office workers	ICE: Focus on short-term productivity effects (i.e. negative influence of intervention on productivity) – mostly non-significant effects Quality: Larger and longer-term randomized-controlled trials are needed to fully assess long-term impact on health- and work-related outcomes	(279)

AJ Defined as programmes that “provide an ongoing, integrated program of health promotion, and disease management that integrates specific components into a coherent, ongoing program, which is consistent with corporate objectives and includes program evaluation of clinical and/or cost outcomes”

	E: Pooled effect size from meta-analysis of –77 min of sedentary time per 8-hour workday	(279)
Organisational travel plans ^{AK}	IE: Insufficient evidence to determine whether organisational travel plans are effective for improving health or changing travel mode. Quality: More high-quality evidence is needed	(297)*
Physical activity programmes at work	NE: No evidence for an effect on workplace stress, work satisfaction or productivity	(298)
Workplace exercise programmes	NE: Little effect on muscle flexibility, body weight, body composition, blood lipids, blood pressure	(220)
Nutrition and diet		
Worksite nutrition programmes	CE: Costs of studies were not assessed, 15 of 17 studies found a positive impact on nutritional knowledge, food intake and health, 13 on absenteeism and presenteeism. Productivity can be raised by 1%-2% Quality: Limited amount of evidence, diversity in design and interventions	(282)
Nutrition programmes that include point of purchase information and environmental supports (individual and organisational approaches)	E: Effective in influencing employee nutrition habits while at work	(292)
Dietary interventions to prevent cancer	E: Interventions which targeted fruit and vegetable intake were most likely to be successful in worksites. Evidence of small positive effects on reducing fat intake	(283)
Fruit & vegetable consumption	NCE: Interventions that rely on dietary counselling, telephone contact, worksite promotion or other methods to encourage change in dietary behaviour were not highly effective or cost-effective. Only five out of 23 interventions are less than a \$50,000 per disability-adjusted life year cost-effectiveness threshold, and even the most effective intervention can avert only 5% of the disease burden attributed to insufficient fruit and vegetable intake.	(299)
Worksite programmes to prevent or reduce obesity over the long term	NE: Not shown to be effective	(282, 288)
Smoking and alcohol		
Smoking bans in the workplace	E: More effective than limiting smoking locations in decreases number of smokers and number of cigarettes smoked per continuing smoker	(283, 300)
Smoking cessation programmes	E: Strong evidence that some interventions directed towards individual smokers increase the likelihood of quitting smoking: individual and group counselling, pharmacological treatment to overcome nicotine addiction, and multiple interventions targeting smoking cessation as the primary or only outcome. Self-help interventions and social support are less effective (low absolute numbers)	(301)*
	NE: No effect detected of comprehensive programmes targeting multiple risk factors in reducing the prevalence of smoking, Self-help smoking cessation programmes (computerized or paper-based) had little effect Further high-quality research is needed, especially in low- and middle-income countries	(301)*
Nicotine vaccines	NE: No evidence that nicotine vaccines enhance long-term smoking cessation. Rates of serious adverse events recorded in the two trials with full data available were low, and the majority of adverse events reported were at mild to moderate levels. The evidence available suggests nicotine vaccines do not induce compensatory smoking or affect withdrawal symptoms. No nicotine vaccines are currently licensed for use in any country but a number are under development	(302)*

AK Travel plans are interventions that aim to reduce single-occupant car use and increase the use of alternatives such as walking, cycling and public transport, with a variety of behavioural and structural components.

Interventions for preventing injuries in problem drinkers	E: Interventions for problem drinking appear to reduce injuries and their antecedents (e.g. falls, motor vehicle crashes, suicide attempts)	(285)*
Alcohol and drug testing of occupational drivers	IE: Insufficient evidence to assess to whether they prevent injury or absence from work related to injury	(300, 303)
Alcohol ignition interlock programmes	IE: Too few high-quality studies were available to ascertain effectiveness. The interlock programme appeared to be effective while the device was installed in the vehicle, but no evidence on effectiveness after removal was found	(304)*
Other		
Workplace interventions in promoting breastfeeding among women returning to paid work after the birth of their child	IE: No randomized or quasi-randomized trials evaluated the effectiveness	(305)*
Programmes restricted to offering information or advice on health issues	NE: No evidence for an effect	(306)
Biofeedback training ^{AL}	NE: No evidence for an effect on upper extremity MSD outcomes	(220)

F. Incentives and subsidies

The overall costs and benefits of an OH programme might not be equally divided over the different parties affected by it, making a case for regulations and subsidies to ensure the incentives to implement the programme are compatible and aligned. For instance, when a firm has no benefit from an OH programme, but the employees do, the government might impose regulations that oblige firms to invest in the programme, can provide subsidies to promote investment, can lower insurance premiums, or introduce tax breaks. In Table 9 below, Elsler et al. discuss the latter (incentives), Tompa et al. the former (regulations).

At the enterprise level, some employers have made use of incentives to “nudge” or stimulate the behaviour of employees, causing them to act more healthily (307-312).

Since these programmes are often considered to be in a grey zone between occupational health and economic interventions, we do not extensively discuss the topic here, but refer to Asche and Aven (313), Cagno, Micheli (314) and Kankaanpaa, Suhonen (315), who provide thorough analyses of the rationale for incentives.

A central finding is that both government (external) incentives and insurance-related economic incentives (where specific prevention efforts are rewarded according to a predetermined model) seem effective for stimulating investment, but combining them would prove even more effective (316). Several of the preceding reviews also discussed incentives, and their conclusions on this topic have been summarized in Table 9.

AL Biofeedback training uses monitoring instruments to provide information about increased muscle tension

Table 9 | Reviews on OH incentives and regulations

[asterisks (*) = Cochrane systematic review, CE = cost-effectiveness, E = effectiveness, IE = inconsistent or inconclusive evidence of effectiveness, ICE = inconsistent or inconclusive evidence of cost-effectiveness, NE = no evidence for effectiveness, NCE = no evidence for cost-effectiveness. Inconsistent, inconclusive, or no effective evidence can pertain to an intervention as a whole, or only certain outcomes (not) associated with it]

FOCUS	KEY FINDINGS	REVIEW
Incentives		
Government incentives	E: Tax reductions can be effective in helping an organisation (paying corporate tax) invest more in OSH Linking economic incentives to audits/intervention programmes was a promising way of improving OSH. Matching funds – where governments provide a grant proportional to the amount of money spent by an organisation on workplace health – are a potential method to improve OSH, but at higher administrative costs Quality: methodological difficulties in evaluating the effectiveness of various incentive schemes	(316)
Insurance-related economic incentives	CE: Moderate evidence that experience rating in worker's compensation (usually a bonus-malus system for insurance premiums based on the individual accident rates of a company) reduces the number of insurance claims	(316)
Prevention of occupational accidents and diseases by using incentives	E: Overall positive results	(317)
	CE: 3 studies (two insurance schemes and an ergonomic subsidy) performed a cost-benefit analysis, resulting in a pay-out ratio from €1.0 to €4.8 for every €1 invested	(317)
Smoking cessation incentives	E: Incentives appear to boost cessation rates	(318)*
Interventions for preventing injuries in the agricultural industry	E: Financial incentives could reduce injury rates	(319)*
Asking participants to pay for a programme	IE: Negatively affects participation but reduces dropout rates. The benefits of incentives cannot be demonstrated in the long term, and may have negative effects	(318, 320)
Incentive- or competition-based smoking cessation	IE: While there are short-term improvements, there is no long-term effect	(321, 322)
Targeted incentives	IE: Appropriately targeted incentives could reduce inequalities in health outcomes, but ongoing assessment of their affordability, effectiveness, cost effectiveness, and unintended consequences is needed	(323)

Regulation		
OH policies	E: Strong evidence that several OH policy levers are effective in terms of reducing injuries and/or increasing compliance with legislation	(319, 324)
Occupational safety and health enforcement tools for preventing occupational diseases and injuries	E: Evidence that inspections decrease injuries in the long term (but not in the short term), while the magnitude of the effect is uncertain. Focused inspections could have larger effects than inspections in general	(322)*
	IE: The effect of fines and penalties is uncertain due to the low quality of the evidence Quality: The quality of the evidence is low to very low and therefore these conclusions are tentative High-quality research is needed	(322)*
Interventions for preventing injuries in the agricultural industry	E: Legislation to ban pesticides could be effective. Legislation expanding the use of safety devices (ROPS) on new tractors was associated with a decrease in fatal injuries	(319)*
Interventions to prevent occupational noise-induced hearing loss	E: Very low-quality evidence that implementation of stricter legislation can reduce noise levels in workplaces.	(116)*



CASE STUDY
Statutory accident insurance of the butchery industry

In the German butchery sector, a combination of both positive premium variations (when investing in occupational safety, such as giving safety training to employees) and funding schemes for safety and health, was introduced. It was associated with 1,000 fewer reportable accidents per year for the sector in Germany, a reduction in costs valued at 40 million euros in six years, and savings of 4.81 euros for every euro invested (13)

VII. Conclusion

In general, existing economic evaluations sketch a mostly bright picture of the benefits of investing in occupational health.

However, many of the available studies and reviews also highlight a need for more high-quality research, both on the effectiveness of interventions on health outcomes, as well as on the financial and economic impact of these programmes. Contradictory indications of reviews can often be explained because of low quality studies, or a general lack of evidence upon economic

outcomes. To strengthen results, more research with a thorough economic component is needed, preferably accounting for the local legal and health-economic context. While the evidence review focused on financial reasons to invest, there are many intangible reasons to invest in occupational health, such as an improved reputation and compliance with the law (325), as a moral obligation, or to bring corporate social responsibility into practice (27, 326). Finally, the conclusions of the reviews should be seen in their context. Much of the research has been conducted in high-income countries, where the prevalence of some hazards and diseases is lower than in low- and middle-income countries.



VIII. Appendix

A. Methodology

This report aims to elucidate the (global) rationale for investment in occupational health and to synthesize evidence from systematic reviews and grey literature (business and policy reports). The first sections (before the evidence review) draw upon a wide variety of published papers and policy documents, but we especially want to acknowledge the excellent work by the WHO, Dorman et al, and SOM (15, 20, 27). Case studies are used throughout the document to illustrate the key points.

The systematic evidence searches were divided into two objectives: one on historical exposures and the other on rising challenges. The author can provide both search strings at request. We thereby focused primarily on (the cost-effectiveness of) occupational health interventions, and less on health promotion, workplace safety, managerial practices, or work organisation interventions (e.g. shift work, working hours, etc.).

EMBASE, PUBMED and Cochrane CENTRAL were searched (without start date) up to November 2017 to find systematic reviews on historical exposures. Search terms included controlled vocabulary (MeSH and Emtree) and free text terms and consisted of three sets: related to 1) economic evaluation 2) historical occupational health exposures - physical, chemical, and biological agents and related diseases, e.g. occupational air pollutants and asthma 3) systematic reviews. Case studies were exemplary studies included in the systematic reviews or directly identified through the search string.

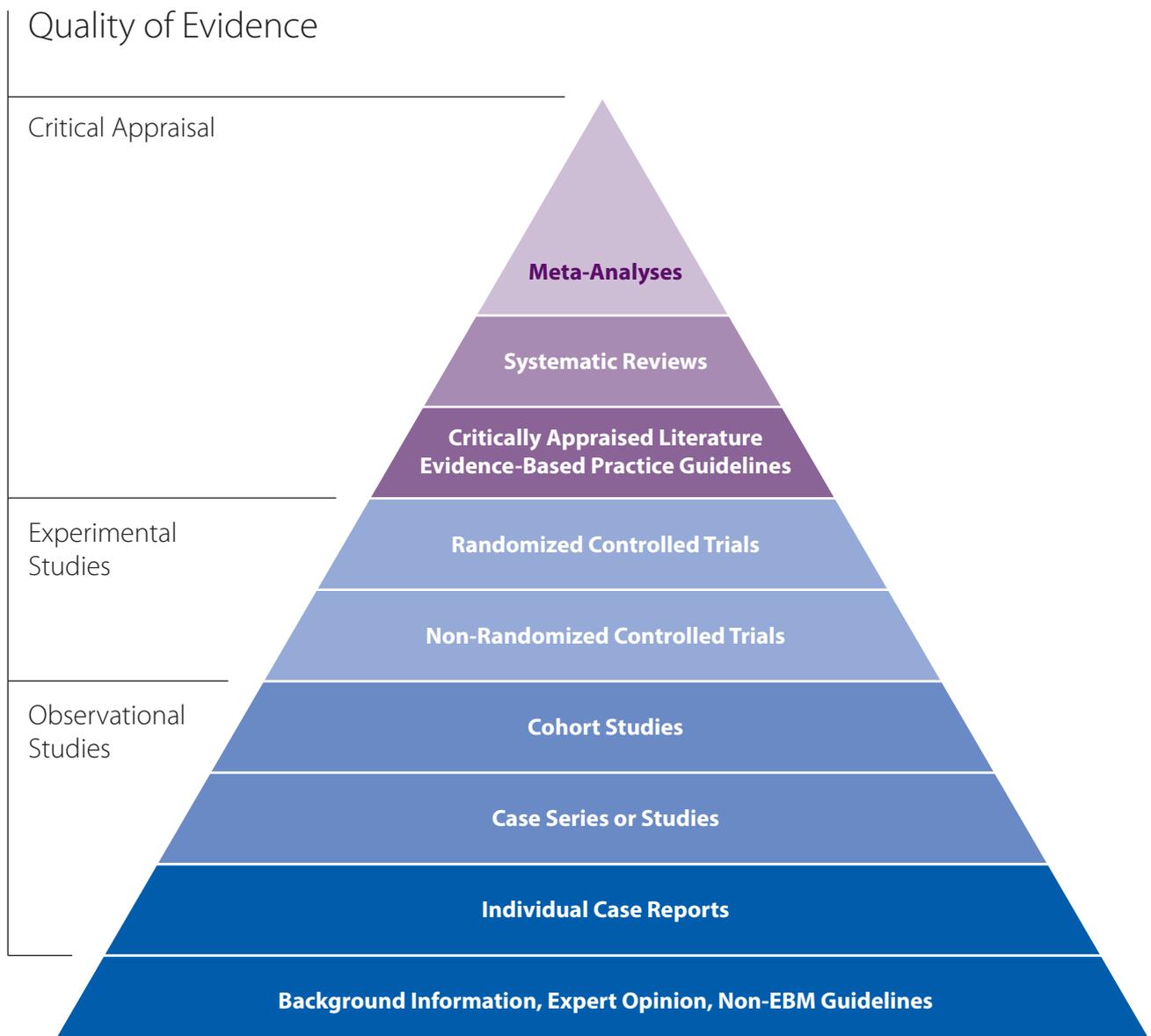
A similar strategy was used for the second objective (rising challenges). Systematic searches were performed in EMBASE, PUBMED and Cochrane CENTRAL from 2007 up to 2017. Search terms included controlled vocabulary (MeSH and Emtree) and free text terms, and consisted of three sets: related to 1) economic evaluation 2) workplace settings or occupational interventions 3) financial variables relevant for firms such as sick leave, presenteeism, disability leave, productivity, etc. Additional case studies (and reviews) were identified through the author's database, and reference screening of published reports, meta-analyses and reviews of reviews on the cost-effectiveness of occupational health (15, 22, 27, 198, 226, 274, 279, 314, 317, 327, 328).

In addition, all reviews (97 in November 2017) from the topical Cochrane database on occupational health and safety were included to incorporate evidence on the effectiveness of interventions (whereas the preceding searches mainly aim to discuss cost-effectiveness). Because of the rigorous methodology of Cochrane reviews, the conclusions of these reviews can be considered to be of higher quality and were therefore highlighted in the text with an asterisk (*).

B.Challenges in systematic reviews (of cost-effectiveness) in occupational health

Several factors contribute to the fact that the results in this report must be interpreted with caution: the low research quality of many studies; the gaps in scientific research (i.e. insufficient quantity of studies); and the

search strategy itself, which only identified systematic reviews and should therefore not be mistaken for a rigorous systematic review of *all* available (primary) evidence. The evidence pyramid is a good illustration of this last fact: while much research has been done on occupational health, it takes time before individual studies find their way into systematic reviews, and in turn to be taken to the top of the pyramid (guidelines).



In this appendix, we want to emphasize some cautionary principles for the analyses in this report. Although it is useful to provide an overview of the existing literature on the cost-effectiveness of occupational health interventions, prudence is needed. Firstly, we chose not to pool or average return-on-investment (ROI) metrics. As previously stated, the methodological quality of many studies was low, causing a risk of bias in their ROI or cost-effectiveness estimates. Pooling together a lot of low quality or biased results will not result in a better view on the real cost-effectiveness. But there are also conceptual issues with deriving conclusions from systematic reviews and meta-analyses. Anderson (330) argues that many systematic reviews, especially in biomedical sciences or pharmacology, aim explicitly to collect the evidence of different effectiveness or efficacy studies to see if findings across studies are robust. While it would be very interesting to know which interventions are cost-effective across studies, the exercise of making a systematic review to determine this, is not necessarily a valid project. Anderson puts forward three arguments for this.

First, there is a very large variation across different cost-effectiveness studies. Not only do economic evaluations incorporate the same variation with which effectiveness studies struggle, a systematic review would also have to deal with the variation in cost settings. In a report on the generalizability and transferability of economic evaluations, Sculpher mentions 26 different sources^{AM} that can cause variability between economic evaluations in the health care sector: the methodology of the economic evaluation can differ, but also the intervention's context, costs and effects and the decision context are almost always locally determined. Very similar variability was noted in our analysis.

Second, economic evaluations often specifically aim to inform decision-makers. This means they have an incentive to make the study as locally relevant as possible, causing reduced external validity. Even if they do not focus on local applicability, the fact that studies should be applicable in other contexts (since they have to inform decision-making) makes the requirements for generalizability of cost-effectiveness results much stronger.

Third, Anderson argues that decision-analytic models are specifically aimed at informing decision-makers while accounting for uncertainty and can already synthesize the available evidence, strongly reducing the need for systematic reviews.

In conclusion, Anderson sees only a limited scope for systematic reviews of the cost-effectiveness of interventions: to evaluate the quality of studies or to study certain methodological aspects of the literature (330).^{AN}

However, with the necessary caution and bearing these arguments in mind, important lessons can still be learned by looking at this literature. Where possible, this report therefore presented disaggregated conclusions (e.g. by intervention type) to reduce heterogeneity across studies and to increase consistency and relevancy.

AM Absolute or relative costs, artificial study conditions, capacity utilisation, case mix, clinical practice variation, compliance, culture and attitudes, demography, disease interaction, economies of scale, epidemiology, exchange rates, geographical setting, health state valuations, healthcare resources, healthcare system, historical differences, incentives, industry-related bias, joint production, opportunity cost, perspective, skills and experience, technological innovation, timing of economic evaluation and treatment comparators (331).

AN Anderson also suggests that systematic reviews can be used to inform decision-making models (to see what key-factors were used in similar models in other contexts), to identify the top 2 or 3 studies that evaluated a similar intervention or (when studies tried to search for explanatory factors that were related to cost-effectiveness) a systematic review to search for factors associated with cost-effectiveness.

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