ORIGINAL ARTICLE

Cost-benefit analysis in occupational health: a comparison of intervention scenarios for occupational asthma and rhinitis among bakery workers

Tim MeijsTer,1 Birgit van Duuren-Stuurman,1 Dick Heederik,2 Remko Houba,3 Ernst Koningsveld,1 Nicholas Warren,4 Erik Tielemans1

ABSTRACT

Objectives Use of cost-benefit analysis in occupational health increases insight into the intervention strategy that maximises the cost-benefit ratio. This study presents a methodological framework identifying the most important elements of a cost-benefit analysis for occupational health settings. One of the main aims of the methodology is to evaluate cost-benefit ratios for different stakeholders (employers, employees and society). The developed methodology was applied to two intervention strategies focused on reducing respiratory diseases.

Methods A cost-benefit framework was developed and used to set up a calculation spreadsheet containing the inputs and algorithms required to calculate the costs and benefits for all cost elements. Inputs from a large variety of sources were used to calculate total costs, total benefits, net costs and the benefit-to-costs ratio for both intervention scenarios.

Results Implementation of a covenant intervention program resulted in a net benefit of €16 848 546 over 20 years for a population of 10 000 workers. Implementation was cost-effective for all stakeholders. For a health surveillance scenario, total benefits resulting from a decreased disease burden were estimated to be €44 659 352. The costs of the interventions could not be calculated.

Conclusion This study provides important insights for developing effective intervention strategies in the field of occupational medicine. Use of a model based approach enables investigation of those parameters most likely to impact on the effectiveness and costs of interventions for work related diseases. Our case study highlights the importance of considering different perspectives (of employers, society and employees) in assessing and sharing the costs and benefits of interventions.

INTRODUCTION

The disease burden of work related exposures can result in high costs for employers, society and workers. For most work related diseases, dose–response relationships indicate that in order to achieve a reduction in ill-health, interventions are needed to lower workplace exposures. Quantitative health impact assessment (HIA) methods can provide a (prospective) analysis of the potential impacts of different intervention strategies on the burden of disease.1 2 This information may subsequently be used in financial evaluations that compare the costs of implementation with the benefits of the reduced disease burden (cost-benefit ratio).

These economic considerations are receiving increased attention in the decision making processes in occupational health, as organisations attempt to maximise the benefits from deploying limited resources.3 While ethical, legal and social aspects must also be considered, the strategy that maximises the cost-benefit ratio will most likely be selected. This type of analysis can also provide insight into the allocation of costs and benefits across different stakeholders. This is especially critical from the employers’ perspective as they frequently cover the costs of interventions. On the other hand, the benefits extend beyond the employer and in addition to improved employee health, may include maintenance of income and reduced pressure on government and private insurance health and welfare programs.4 5

Different cost-benefit analysis methodologies have been proposed and utilised in the scientific literature. Most methodologies focus on (ergonomic-oriented) interventions at the company level.5–8 A few studies performed cost-benefit
analysis on a larger scale, covering, for example, industrial sectors or global regions. The models and methods used in most of these studies are case-specific and thus only applicable for one health outcome or type of intervention. In public healthcare more generic models are available for cost-benefit analysis. Unfortunately, these models do not provide opportunities for studying the effect of specific cost allocations and benefits for different intervention scenarios.

This study presents a methodological framework which identifies the most important elements of a cost-benefit analysis for occupational health settings. One of the main aims of the methodology is to facilitate the evaluation of cost-benefit ratios for different stakeholders (employers, employees and society (tax-payers)). The presented conceptual model for cost-benefit analysis can be seen as an extension of the quantitative HIA method described by Warren et al. The developed methodology is applied to a case study on work related respiratory diseases among Dutch bakery workers. Cost-benefit analyses of two interventions were performed. The first was an educational intervention that was part of a covenant. The second, hypothetical, scenario consisted of health surveillance followed by an individual intervention to reduce exposure for identified high risk workers. The HIA for both scenarios has been reported in an earlier paper.

**DEVELOPMENT OF THE COST-BENEFIT FRAMEWORK**

**Identification of relevant cost categories**

A review of the literature yielded various approaches to cost-benefit analysis for evaluating occupational, public health and medical interventions. Published cost-benefit analyses vary greatly in scope and level of detail but do indicate the most important categories of costs and benefits of interventions. In the Netherlands, a detailed handbook for cost studies related to healthcare issues was developed by Oostenbrink et al. This handbook contains a detailed overview of many relevant cost categories, data sources and calculation methods that are also appropriate for occupational cost-benefit analyses.

Figure 1 shows the conceptual framework including the relevant cost categories and their breakdown into cost elements. The main cost categories identified are: costs of interventions, operating costs, health related costs, customer services and costs associated with liability and safety. We also tried to identify whether these costs should be attributed to employers, employees or society.

**Description of identified cost categories**

**Intervention costs**

The intervention costs consist of six cost elements: (1) investments (eg, machinery, technical control measures), including the costs of advice and installation; (2) training and education associated with the intervention; (3) disinvestments, that is benefits from the sale of old equipment; (4) identification of the intervention population (eg, health surveillance to identify high risk workers); (5) costs related to research activities (eg, intervention mapping or evaluations); and (6) subsidies, which benefit the employer but at the same time can be a societal cost if the subsidies are paid by the government.

**Operating costs**

**Disease related costs**

**Costumer Service**

**Safety**

<table>
<thead>
<tr>
<th>cost elements</th>
<th>General explanation</th>
<th>Aspect ascribed to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit price of equipment / advice costs / installation costs</td>
<td>Additional costs with respect to the old situation</td>
<td>Employer</td>
</tr>
<tr>
<td>Training</td>
<td>Costs of intervention related training</td>
<td>Employer</td>
</tr>
<tr>
<td>Disinvestments</td>
<td>Savings due the sale of current machines, furniture</td>
<td>Employer</td>
</tr>
<tr>
<td>Identification of intervention population</td>
<td>Environmental impact, diagnostic work</td>
<td>Employer</td>
</tr>
<tr>
<td>Intervention implementation and evaluation</td>
<td>Intervention in a ‘study setting’ might include intervention mapping and evaluation activities</td>
<td>Employer</td>
</tr>
<tr>
<td>Subsidy</td>
<td>Environmental subsides</td>
<td>Society (tax payer) or Industry</td>
</tr>
<tr>
<td>Cost of maintenance</td>
<td>Change in costs compared to the old situation</td>
<td>Employer</td>
</tr>
<tr>
<td>Use of space</td>
<td>Change in costs compared to the old situation</td>
<td>Employer</td>
</tr>
<tr>
<td>Energy costs</td>
<td>Change in costs compared to the old situation</td>
<td>Employer</td>
</tr>
<tr>
<td>Interest costs</td>
<td>Costs associated with the finance of the intervention</td>
<td>Employer</td>
</tr>
<tr>
<td>Personnel costs</td>
<td>More or less personal needed related to intervention</td>
<td>Employer</td>
</tr>
<tr>
<td>Waste / fall out</td>
<td>Change in costs compared to the old situation</td>
<td>Employer</td>
</tr>
<tr>
<td>Administrative costs</td>
<td>Costs of additional administration (eg, protocols)</td>
<td>Employer</td>
</tr>
<tr>
<td>Direct and indirect medical costs</td>
<td>Costs for treatment, medication, transport, etc</td>
<td>Employer / society</td>
</tr>
<tr>
<td>Disability</td>
<td>Medical costs: a disabled worker will have medical costs comparable to the described cost element</td>
<td>Employer / society</td>
</tr>
<tr>
<td>Cost of income</td>
<td>Quality of Life: Costs associated with the willingness to pay for a healthy life year</td>
<td>Employer / society</td>
</tr>
<tr>
<td>Reintegration</td>
<td>Decrease of income as a result of disease/disability</td>
<td>Employer / society</td>
</tr>
<tr>
<td>Productivity</td>
<td>Costs for rehabilitation of workers (to another job)</td>
<td>Employer / society</td>
</tr>
<tr>
<td>Service</td>
<td>Costs of work time loss (absence/disability)</td>
<td>Employer / society</td>
</tr>
<tr>
<td>Quality of the product</td>
<td>Additional costs associated with a change in productivity</td>
<td>Employer / society</td>
</tr>
<tr>
<td>Safety behavior</td>
<td>Change in process might affect the service of the company, eg, reliability of the supply, flexibility of the process</td>
<td>Employer / society</td>
</tr>
<tr>
<td>Prevention of almost) accidents</td>
<td>Increase/decrease quality might result in an increase or loss of clients</td>
<td>Employer / society</td>
</tr>
<tr>
<td>Costs related to liability/lawsuits</td>
<td>Increase/decrease with respect to the old situation</td>
<td>Employer / society</td>
</tr>
<tr>
<td>Fines</td>
<td>Increase/decrease with respect to the old situation</td>
<td>Employer / society</td>
</tr>
<tr>
<td>Claims</td>
<td>Increase/decrease with respect to the old situation</td>
<td>Employer / society</td>
</tr>
</tbody>
</table>

**Figure 1** Schematic overview of the conceptual approach for cost-benefit-analysis.
Operating costs
Operating costs are associated with the operational processes. Well known cost elements are administrative costs and utility costs such as those related to energy and housing (space). Other important costs are maintenance and cleaning costs and wastage/fall out. A last category, interest costs, is relevant when a company borrows money to (partially) finance an intervention.

Disease related costs, productivity loss and sickness absence
This cost category contains all cost elements directly and indirectly associated with (the change in) the disease burden resulting from interventions. A first important cost element here is direct and indirect medical costs. Direct medical costs include expenses related to medication, hospitalisation and visits to the general practitioner. Indirect costs include, for example, costs of transportation.

The second cost element, productivity loss, is associated with sickness absence but might also include productivity losses due to sick workers continuing to work (presenteeism). Traditionally this is calculated by multiplying the units of lost time by the unit salary costs (human capital method). It is nevertheless acknowledged that in most cases the true costs will depend on the way the ill worker is replaced and if productivity loss occurs. So the real costs can differ substantially. Koopmanschap et al provide a detailed overview of factors that determine if and why productivity loss due to sickness absence might be limited.

One of the main factors is the elasticity in a company, meaning that the actual work time loss results in less productivity loss because people are not 100% efficient and some of the work might be performed by the already available work force without additional costs.

In case of chronic illness or (partial) disability, in most countries the employer has to pay the salary of the disabled worker. In the Netherlands, the employer usually has to pay the worker’s wages for the first 2 years of illness or disability. Rehabilitation of the sick worker and administration involve additional costs. In the Netherlands the employee receives payments from social security funds after 2 years of disability, which continues until re-employment or age 65 (the legal pension age). In most cases the employee loses part of their income.

Longitudinal studies indicate that even if exposure ceases, asthma symptoms can persist depending on factors such as exposure duration and the causative agent. A recent review of the socio-economic effects of occupational asthma reported that 25–38% of workers with occupational asthma experience prolonged work disruption. (Re-)employment of a worker also depends on socio-demographic factors and the presence of a (national) re-employment program.

Exact numbers are expected as a result of a specific intervention. Implementation of the intervention might effect the company’s customer service. For example, speed of production, product quality, delivery reliability, flexibility and customer service might temporarily be affected, resulting in reduced income or compensation claims. Finally, implementation of the intervention might result in changes in the safety and liability costs of the company.

DESCRIPTION OF THE COST-BENEFIT CASE STUDY

Intervention scenarios
In this cost-benefit study two previously described intervention scenarios were evaluated. In short, the first scenario included an industry-wide education program where individual companies were visited by consultants who supplied information on the risks of exposure and provided guidance on good work practice. The impacts of this intervention program on exposure to flour dust and the disease burden were evaluated quantitatively.

The second scenario is a hypothetical health surveillance intervention program where high risk workers, defined as workers sensitised to occupational allergens and/or reporting upper respiratory symptoms, are identified through health surveillance. Health surveillance is carried out every 3 years for the full 20-year simulation period. All workers identified receive an individual workplace intervention, which is assumed to reduce their exposures by 90%.

The described cost-benefit analyses are based upon an assessment of the change in disease burden. A recently developed dynamic population based model for respiratory health effects in bakery workers was used to simulate the health impact of the intervention scenarios. The model simulates the development of disease in a fixed worker population of 10 000 workers, the approximate size of the Dutch bakery population at risk, longitudinally over a period of 20 years. The model simulates the development of work related sensitisation, work related upper respiratory symptoms, work related lower respiratory symptoms and work disability in each bakery worker. Prevalence and incidence rates were extracted from the results matrices for all years and averaged over all 40 runs to correct for stochastic (population) variation. The prevalence rates were used to calculate the disease burden (eg, number of disease years) for the different outcomes.

INPUT FOR THE COST-BENEFIT ANALYSIS

The estimations of the input values are discussed by cost category. An Excel spreadsheet was used to calculate the costs and benefits for employers, employees and society by cost category. In addition, total costs, total benefits, net costs and the benefit-to-costs ratio were determined.

Intervention costs

Scenario 1: covenant intervention
We obtained a detailed overview of the costs of the covenant intervention program from the initial budget and partially from the actual accredited costs. The available information attributed costs to specific stakeholders. The intervention included educational and training components and costs for the health surveillance and very limited clinical care activity. These activities were not followed by any workplace intervention but did contribute to the education of workers (eg, regarding risk perception). In total, the costs of the covenant intervention program were €5 438 000, of which €2 164 000 was paid by the employers and €1 274 000 by the government. A detailed overview of the costs can be found in the online appendix 1.
Workplace

Scenario 2: health surveillance and individual exposure reduction
The HIA indicated that approximately 4200 high risk individuals would be identified over a 20-year period, resulting in a similar number of individual interventions. The content of these interventions and thus the costs will vary substantially. The exact interventions and their impact will depend on the characteristics of the workplace (eg, whether or not controls are already in place) and the number of workers possibly benefitting from the same intervention. The anticipated interventions may involve engineering controls (eg, local exhaust ventilation), administrative controls (eg, training) and personal protective equipment. The available information does not permit calculation of a reliable estimate of the costs of individual interventions. We used the cost-benefit analysis to estimate the maximum acceptable intervention costs per sick worker based upon the projected benefits of the estimated reduction in disease burden.

Operational costs
We assumed that operational costs were not substantially affected by the intervention scenarios evaluated in this study. There might be small differences in energy use and the amount of waste/cleaning, but these are expected to cause marginal changes in costs. Also, no large additional administrative burdens are expected for either industry or regulators. It was therefore decided to omit this cost category from the final cost-benefit analyses for both scenarios.

Disease related costs
The HIA provided data on the number of sick workers and the case rates for all disease conditions. This allowed the number of disease years for the different outcomes over the complete evaluation period to be calculated. The number of disease years for disability could not be obtained directly from the HIA since disabled workers leave the simulated worker population. Here we used the total number of ‘new’ cases to estimate the costs, as will be described in detail below. Table 1 provides information on the changes in disease burden for the two intervention scenarios. One specific result is the increase in rhinitis symptoms for the health surveillance intervention. The majority of the high risk workers are only identified after they have developed upper respiratory symptoms. Their exposure is then reduced and as a result so is their likelihood of progressing to the next disease stage. As a consequence, workers are less likely to change to another disease state resulting in an increase in disease years for upper respiratory symptoms.

Direct and indirect medical costs
Medical costs, sickness absence and productivity loss associated with the disease burden were estimated so that the cost of the disease burden could be calculated. The Dutch National Institute for Public Health and the Environment published a report in 2004 on the costs of asthma and chronic obstructive pulmonary disease. The total direct medical costs of asthma per patient are expected to increase from €511 to €737 between 2000 and 2020. We used the average of €524 per patient in our calculations. An annual cost of €321 has been estimated for indirect (non-compensated) costs, such as transportation. Less detailed information on costs is available for upper airway symptoms. Direct medical costs for allergic rhinitis are estimated to be €41 per patient annually, and cover drug costs, general practitioner visits and hospital treatments. No data are available for non-compensated costs, but assuming a comparable relative contribution of these costs as for asthma symptoms, an estimate of €30 per patient annually is reasonable. All these costs were available for general asthma and rhinitis and not for specific occupational symptoms.

Productivity loss
No Dutch data are available on the number of days a worker with occupational rhinitis or asthma is absent from work as a result of their illness. Some studies on occupational asthma report the costs of work time loss but most do not specify how these costs were assessed. Some international studies on asthma in the general population do report on work absenteeism as a consequence of asthma. Although these studies do not consider work related asthma specifically, they do provide an indication of the work time loss due to asthma symptoms. The estimates range from 1 to 28 days of absence with average values of between 4 and 10 days. The UK Health and Safety Executive reported that between 5.5 and 28 work days were lost in 2008/2009 as a result of occupational respiratory symptoms. It is likely that the sickness absence figures for general asthma underestimate sickness absence due to occupational asthma, since here the causal factor is exposure in the workplace. Based upon the available information, an average of 10 work days lost per working year for an individual with occupational asthma in this sector seems a reasonable estimate.

For rhinitis less evidence is available on the link between illness and absence from work. Two US studies estimated 0.34 and 3.6 lost work days per year as a result of allergic rhinitis in the general (working) population. It is likely that, as for occupational asthma, work related allergic rhinitis is more severe during work activities and thus results in more work days lost than allergic rhinitis associated with common allergens. We estimate that work related rhinitis results in an average of 5 lost work days per annum.

To estimate the cost of lost work days, the costs of 1 work day were calculated. An average daily wage was calculated based on information obtained from the collective labour contract and including additional costs (social security, insurance and pension). This figure was then corrected for the average elasticity figure of 0.8 obtained from Koopmanschap et al., meaning that for every 1 h of absence productivity decreases by the equivalent of 0.8 h. The cost of a lost work day was calculated as €202.

Work disability
We assumed the incidence of new disability cases would be equally divided over the full 20-year simulation period. Given the

<table>
<thead>
<tr>
<th>No intervention</th>
<th>Covenant intervention</th>
<th>Health surveillance intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>New cases</td>
<td>Disease years</td>
<td>New cases</td>
</tr>
<tr>
<td>Rhinitis symptoms</td>
<td>2436</td>
<td>20591</td>
</tr>
<tr>
<td>Asthma symptoms</td>
<td>1404</td>
<td>11968</td>
</tr>
<tr>
<td>Work disability</td>
<td>555</td>
<td>—</td>
</tr>
</tbody>
</table>

Table 1 Number of new cases and disease years of workers with rhinitis and asthma symptoms and of disabled workers calculated with the dynamic population-based health model with or without implementation of interventions for a worker population of 10 000 workers over a period of 20 years.
Results for scenario 1: covenant intervention program  
An overview of the costs and benefits for the different cost categories and for the employer, employee and the society, is presented in table 3. Overall, implementation of the covenant intervention program resulted in a benefit of €16 484 546 over a period of 20 years for a population of 10,000 workers. Implementation of the intervention is cost-effective for all parties.

| Scenarios | Costs of intervention | Avoided medical costs | Avoided absence | Avoided disability costs | Avoided loss of income | Total net benefit | Total cost of occupational health | Cost-benefit analysis of the covenant scenario shows how a relatively limited |
|-----------|------------------------|-----------------------|-----------------|-------------------------|-----------------------|------------------|----------------------------------|________________________________________________________________________|
| Covenant  | −€1 274 000            | €1 376 835            | −€5 802 450     | €6 098 538              | −€8 032 243          | €6 201 373      | €1 264 000                       | −€1 264 000                                                                 |
| scenario  |                        |                       |                 |                         |                      |                 | −€3 438 000                      | −€3 438 000                                                                 |
| Health    | Costs of intervention  | Unknown               | Unknown         | Unknown                 | Unknown              | Unknown         | Unknown                          | Unknown                                                                                 |
| surveillance | Avoided medical costs | €3 183 690            | Unknown         | Unknown                 | Unknown              | Unknown         | Unknown                          | Unknown                                                                                 |


RESULTS OF THE COST-BENEFIT ANALYSIS

Results for scenario 1: covenant intervention program  
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| Health    | Costs of intervention  | Unknown               | Unknown         | Unknown                 | Unknown              | Unknown         | Unknown                          | Unknown                                                                                 |
| surveillance | Avoided medical costs | €3 183 690            | Unknown         | Unknown                 | Unknown              | Unknown         | Unknown                          | Unknown                                                                                 |


Results for scenario 2: health surveillance intervention  
Table 3 shows the benefits for the main cost categories for scenario 2. Overall, there was an estimated benefit of €44 659 552 for the full 20-year period for a population of 10,000 workers. A total of 4200 individual interventions was estimated. Based on these figures the average cost of an individual intervention needs to remain below €10 000 per intervention for there to be a net benefit. If the interventions are fully paid for by the employers, the average cost must remain below €4650 per individual intervention so as not to exceed the employer’s benefits. However, it should be acknowledged that in many cases workplace changes are likely to affect more than one worker and changes will also impact on future workers, which further complicates the assessment of intervention costs at an individual level.

SENSITIVITY ANALYSIS

We performed a local sensitivity analysis to assess the robustness of our cost-benefit model. The inputs of our cost-benefit calculation were changed by 5% for each calculation and the impact of this on our outcome values evaluated. We performed this analysis for the covenant intervention only since all inputs were only available for the cost-benefit model. We expressed the output as a sensitivity score which was calculated by dividing the percentage change in our output value by the 5% change. In figure 2 we present the sensitivity score for the different input parameters of our model. As expected, the sensitivity of our outcome varies substantially depending on the input parameter. The output is most sensitive to the input values for the number of disease years of asthma and disability as well as the estimation of the cost of a work day.

DISCUSSION

Cost-benefit analyses of intervention policies in the field of occupational health are scarce. Published approaches vary substantially between studies as do the data requirements and level of detail. As no ‘off the shelf’ model or methodology was available for this study, a framework was developed based on earlier work and expert input. It became very clear that the details of cost-benefit analyses will vary between studies and countries. However, the general framework will apply to most occupational interventions, even in an international context.

The present study shows how cost-benefit analyses might be used to establish if an intervention strategy will lead to (long term) monetary benefit for different stakeholders or to determine what acceptable intervention costs might be. The analysis of the covenant scenario shows how a relatively limited...
Figure 2  Tornado plot of sensitivity analysis for all cost-benefit analysis input parameters. wd, work day; wy, work year.
are probably quite sensitive to how long workers are disabled. So more information on the likelihood of becoming disabled due to asthma, and the duration of the disability before re-integration, and how many workers are actually permanently disabled, is urgently needed, especially given that currently these are some of the least understood aspects of occupational asthma.

In general, estimation of the effect of an exposure-oriented intervention can be problematic. As exposure may be reduced immediately or more gradually over time, the chosen scenario greatly determines the health impact of an intervention. Second, after implementation of an intervention there is usually only a limited impact on the population disease burden in the short term. The greatest impact occurs after several years (or even decades) depending upon latency and rate of disease progression. In these cases, costs and benefits should be calculated over a long period as otherwise the health benefits will be underestimated. A drawback of this is that factors like indexation (not taken into account in our analyses) are likely to play an important role in the estimation of actual costs over time. In addition, it was not possible to determine the price year for all our inputs, so in general we tried to obtain the most recent available information for all parameters.

These cautionary notes notwithstanding, this study provides important insights and guidance into developing strategies for the implementation of effective exposure based interventions in the field of occupational medicine. Using a model based approach enables further investigation of those parameters most likely to impact on the effectiveness and costs of interventions for work related diseases. Our case study highlights the importance of considering the different perspectives of employers, society and employees in assessing and sharing the costs and benefits of interventions.

Competing interests None.

References

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*Occup Environ Med* 2011 68: 739-745 originally published online May 31, 2011
doi: 10.1136/oem.2011.064709

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