Estimation of Net-Costs for Prevention of Occupational Low Back Pain: Three Case Studies from the US

Supriya Lahiri, PhD¹, Judith Gold², ScD, Charles Levenstein, PhD³

¹Department of Economics, University of Massachusetts Lowell, Falmouth Hall 302D, One University Avenue, Lowell, MA 01854, ²Department of Work Environment, University of Massachusetts, Lowell, Massachusetts, ³Department of Work Environment, University of Massachusetts Lowell.

Background We are focusing on efforts to develop a model approach at a micro or company level for the economic evaluation of interventions to reduce work-related low back pain (LBP). Our study provides a simple transparent framework to estimate the net economic costs of investments in ergonomic interventions at the company level to reduce occupational morbidity.

Methods We have developed an instrument for data collection and data analysis at the facility level known as the net-cost model. All costs are annualized costs and are calculated at the level of an individual organization. Costs of low back pain interventions are defined comprehensively by incorporating not only the costs of investment of equipment and labor for the interventions but also by taking into account the avoided costs of lost work time, medical care costs and productivity improvements. Three case studies have been performed based on data from three companies in the manufacturing sector of the United States using the above approach.

Results Our net-cost estimates for the three case studies consistently show that ergonomic interventions applied appropriately can result in substantial cost savings for the companies.

Conclusions Although we do not like to generalize on the basis of three case studies, our analyses show that it might be in the economic interest of management to play a more active role to prevent back pain. In our attempts to gather useful cost information from a number of companies, we have found that the retrospective gathering of cost data, even on interventions deemed effective by corporate innovators, proved to be extremely difficult. Hence, we have concluded that it is essential to incorporate a protocol for collecting cost and effectiveness data in the standard operating procedures of ergonomists and companies introducing such innovations. In the near future, we aim to validate the net-cost model for the monitoring and reporting of such data through prospective studies in a variety of industrial settings and in countries at various stages of economic development.

KEY WORDS: low back pain; ergonomic interventions; net-cost model; economic evaluation of occupational interventions

INTRODUCTION

Low back pain is a frequent phenomenon in industrialized countries. Data from the developing nations are limited. However, China reports similar levels of back pain as those of the industrialized nations [Jin, et al., 2000]. More than 26 million Americans of working age have frequent low back pain [Lawrence et al., 1998]. Aggregate annual productivity losses in the United States due to chronic back pain have been estimated at $28 billion [Rizzo et al., 1998]. Epidemiologic studies have linked back pain to lifting, heavy physical work, twisting and bending, and exposure to whole body vibration. [Bernard, 1997; National Research Council, 2001]. Although some of the highest prevalences of back pain occur in lumber and building material retailing, construction, patient handling, and in transportation [Guo et al., 1999], a wide spectrum of economic sectors including services, manufacturing and mining are also affected [Behrens et al., 1994]. Much of low back pain, however, can be prevented. Interventions including engineering controls (such as mechanical lifts and dollies), lifting training, and back belts have been implemented in the workplace with the aim of preventing back problems. However, studies identifying the costs and effectiveness of such interventions are few.

In our past WHO study [Lahiri et al., 2004] we examined the cost-effectiveness of various interventions to prevent work-related LBP using the WHO approach [Lauer et al., 2003] to measurement of health-adjusted years of life at an economy wide or macro level. We used specific micro level studies of ergonomic interventions from the literature to estimate their effectiveness in reducing risks from LBP, made assumptions about applying them at a macro level and generated cost effectiveness ratios of specific interventions at the global level for specific WHO sub-regions. In the present study, we are focusing on efforts to reduce such work-related “low back pain” by developing a model approach at a micro or company level known as the net-cost model.

Address all correspondence to: Dr Supriya Lahiri, Professor, Department of Economics, University of Massachusetts Lowell, Falmouth Hall 302D, One University Avenue, Lowell, MA 01854. Tel. 978-934-2789; FAX 978-934-3071; Email. Supriya_Lahiri@uml.edu
We have solved the net-cost model with the data provided by three companies in the US. All costs were converted to annualized cost flows at the level of an individual organization. Company A is a small wood-processing manufacturing plant owned by a multi-national corporation, with ergonomic interventions implemented for laborers and assemblers. Company B, a large multi-national automotive supplier, implemented interventions for low-back pain in office workers. Company C is a major manufacturer of truck and automotive bodies and engines. Interventions were implemented for assemblers in several different lines.

In our previous study, we concluded that interventions are cost-effective in both developed and developing countries for their health effects alone, even ignoring the possible productivity effects. In our current work, we have developed and applied a modeling approach at the company level that evaluates the cost effectiveness of low back pain interventions by addressing net costs of interventions, that adjusts the investment costs of interventions by including changes in productivity and cost savings due to prevention of illness.

Our goal in the current study is to address the economic cost of interventions more comprehensively. For example, the costs of interventions will include not only the investment costs of the interventions but also takes into account the avoided costs of lost work time and medical care costs and productivity changes. The critical question is: What are the net costs of these interventions and to what extent do they reduce the incidence of back pain?

LITERATURE SEARCH

We found that the current literature to be extremely limited in reporting cost information concerning interventions. In addition, we also found a plethora of inconsistent and/or non-comparable definitions of effectiveness. As one aspect of the effort to develop useful cost information, we have surveyed companies reporting model cases to the Occupational and Health Administration (OSHA). We find that the retrospective gathering of cost data, even on interventions deemed effective by corporate innovators, proved to be extremely difficult. The companies also did not have good effectiveness data. Although they supported the idea of our study, many company officials indicated that the cost of developing such data retrospectively was prohibitive.

A literature search of English language articles published in the United States and Canada was conducted to ascertain the usefulness of current ergonomic interventions with respect to economic evaluation. Search keywords included: low-back pain, intervention, back pain, back, musculoskeletal pain, ergonomic, cost-benefit. The current literature concerning interventions for LBP was extremely limited in reporting of cost information. Four of twenty initially identified articles only provided limited qualitative descriptions of the interventions.

Analyses based on costs were infrequent; a majority of the remaining sixteen articles had virtually no \((n = 6)\) to minimal \((n = 7)\) cost information. Only three studies provided more than cursory cost details. In the most complete evaluation of intervention costs, an econometric model was formulated [Lanoie et al., 1997] to evaluate factors affecting the number of back-related disorders in a beverage warehouse. Confounders such as age, seniority, wage and overtime hours were considered for the model. However, intervention effectiveness was assumed and not based on actual incidence data. Some data on costs of interventions for performing patient handling tasks are also available [Evansoff et al., (1999) and Brophy et al. (2001)]. Each study has gaps in addressing the complete cost of the interventions implemented.

Similar results were obtained through a literature search published in languages other than English conducted by TNO (The Netherlands Organization for Applied Scientific Research) in the Netherlands. Through a search of the TNO Work and Employment database and through inquiries to targeted experts, several articles were identified for review. None of these articles provided comprehensive information related to costs of intervention and their effectiveness as required by our study. Two studies provided some cost information. In a back school training program in bus drivers, costs of back school program per employee included the total training costs as well as of wages due to lost working hours [Versloot et al., 1992]. The savings generated through decrease in absenteeism measured the effectiveness of the intervention. A frequency analysis of the length of absenteeism obtained by comparing the results of the control group versus that of the experimental group showed a change in the distribution of the length of absenteeism over time which resulted in a total annual savings of $100,000 for the company.

A cost-benefit analysis of a comprehensive ergonomics intervention program in the petroleum industry compared costs of investment and loss of production due to taking time off from work for training [Dekker et al., 2000]. Benefits included avoided costs due to a reduction in back related sick leave. The mean benefit estimated due to reduction of sick leave was 350.00 Dutch guilders ($183.533) per intervention year versus an investment of 172.000 Dutch guilders ($90.193). The analysis shows a return of almost 100 percent on investments.

METHODS

Recent analyses of procedures for evaluating interventions for occupational safety and health of workers [Mossink, 2002; Dorman, 2000; Barefoot Economics, 2002; DOD, 2002; Oxenburgh, 1991, 94; Reville et al., 2001] have identified the different factors that play a crucial role in determining the costs of these interventions. The identified costs can be classified from the perspective of the company; worker; economy; and society as a whole.

These cost categories are not mutually exclusive and there may be a substantial overlap. For example, the cost to the company and worker would both be included as costs to the economy. However, certain costs, for example, the cost of worker displacement due to the introduction of interventions that cause enhancement in productivity (especially relevant for developing economies) and might lead to unemployment would be included as costs for the economy, but not for the particular company or the injured worker. Again, certain unmeasured costs that are imposed...
on families of injured workers, for example, role reversal among spouses may not enter the market directly. These non-market costs may be ignored as costs at the economy wide level, nonetheless they may be highly significant as components of societal cost [Levenstein, 1999].

One of the main purposes of economic analysis of interventions for occupational safety is to determine if investments in interventions are profitable from the company’s point of view either in the short run or in the long run. If these investments were profitable then it would be in the interest of the company to implement these measures. Simply making firms aware of the profitable possibilities of such interventions may be sufficient to yield “win-win” solutions to certain problems in occupational safety. However, it is also possible that the investments in these interventions are not worthwhile from the company’s point of view because a substantial portion of the costs of these injuries may not be borne by the company. Yet there may be significant costs of occupational injuries for the economy as a whole. Costs of injury to the worker may be paid, at least in part, through workers compensation insurance or some other form of social security, and hence may be obscured or hidden to the company that is employing dangerous technologies. Hence, companies might ignore safety precautions that could have prevented the injuries. These “moral hazard” issues, as they are known in the economics literature, may be addressed in a limited way through an increase in insurance premium liability for the companies when injuries occur (“experience rating”). Nevertheless, the essential purpose of insurance is the pooling of risk, rationalizing costs and, thus, permitting the costs of injury to be built into the price of the product.

In certain cases, family situations or outcomes due to the injury of the worker may not enter the market directly, hence may not show up as economic costs. Still, there could be significant costs at the societal level. In these cases the normative implication might be intervention by the government (through mandatory legislation or incentives provided through subsidies) to correct the market failure. Thus, economic analysis is useful, whether it proscribes feasible action at the company level or suggests the necessity of government intervention.

An overview of a comprehensive model is shown in Chart 1 as a flow diagram. There are four essential components in this framework: first, the cost of equipment and labor of the intervention enters the cost equation as a positive component; second, the degree of effectiveness of the interventions essentially determines the value of the avoidable costs of injuries and illnesses; third, the increase in productivity results principally from the technological design of the equipment; fourth, the displacement of workers that might result from an increase in productivity of the intervention. While both the second and third components enter the accounting equation as negative expressions and help to reduce the real cost of the intervention, the cost of retraining for displaced workers enters the equation as a positive cost from the societal point of view.

Our goal in this study, however, is to develop a standardized tool for economic analysis that would measure the net costs of interventions for the primary prevention of low back pain primarily from the company’s point of view. Due to paucity of data, we have implemented a simple version of the net-cost model that can be implemented with the data that the companies and insurance companies can provide.

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1 Hence, this model ignores the unmeasured societal costs that are imposed upon families but do not show up as “economic costs” that enter the market directly.
Chart 1: A Model Overview: Annualized Net-Cost of Interventions for Preventing Occupational LBP
Model Equations

The model used in our case studies to estimate the net-costs of interventions has been adapted for companies that had implemented ergonomic interventions and made the data available to us. The equations of the model are based on the information provided by a number of studies [Dorman, 2000; Barefoot Economics, 2002; DOD, 2002; Oxenburgh, 1991, 1994; Mossink, 2002]. The model essentially is an accounting framework for net costs where net cost is equal to investment cost on intervention equipment plus labor costs involved in implementing the intervention minus avoidable health care costs of illness and injury, productivity losses due to loss in efficiency and absenteeism, and other benefits related to productivity enhancement of all workers subjected to the intervention. All costs are annualized costs and are calculated at the level of an individual organization. Given the investment and labor costs of the intervention, an important factor that essentially drives the model is the degree of effectiveness of the interventions in reducing back pain. Higher the degree of effectiveness of the interventions higher would be the avoidable costs and lower would be the net costs of implementing the interventions. The other important factor that influences net costs is the gain in the coefficient of productivity resulting from the ergonomic interventions. The model equations are specified in Chart 2.

2 Replacement costs and disability costs are not included in our equations used in the three case studies as they were not reported as relevant factors by the companies.
### Chart 2: Model Equations

1. \[
    \text{Annualized Net Economic Costs Of Safety Interventions For Preventing Occupational Low Back Pain (LBP)} = \text{Annualized Additional Direct Investment Costs On Equipment For Interventions} + \text{Annual Labor Costs For Implementing The Intervention} - \text{Avoided Annual Economic Costs Of LBP} - \text{Annual Value Of Increase In Productivity For All Workers Subjected To The Intervention}
\]

2. \[
    \text{Avoided Annual Economic Costs Of LBP} = \text{Avoided Medical Care Costs} + \text{Avoided Reduction In The Value Of Lost Work Time Due To LBP Sick Leave} + \text{Avoided Reduction In Productivity Losses Due To LBP When Not On Sick Leave}
\]

3. \[
    \text{Annualized Net Economic Costs Of Safety Interventions For Preventing Occupational LBP Per Worker} = \frac{\text{Annualized Net Economic Costs Of Safety Interventions}}{\text{(Total Workforce In The Organization)}}
\]

### Direct Costs on Equipment

4. \[
    \text{Total Additional Direct Investment Cost Of Each Equipment} = \text{Total Direct Current Costs Of Investments In Each New Equipment After Intervention} - \text{Total Direct Costs Of Investments In Each Similar Type Of Equipment Prior To Intervention}^3
\]

5. \[
    \text{Total Direct Current Costs Of Investments In Each New Equipment} = \text{Price Of Each New Equipment In 2002 Dollars} \times \text{Quantity Of Each New Equipment}^4
\]

6. \[
    \text{Total Direct Prior Costs Of Investments In Each Similar Type Of Equipment} = \text{Price Of Each Prior Equipment In 2002 Dollars} \times \text{Quantity Of Each Equipment Prior To Intervention}
\]

7. \[
    \text{Capital Recovery Factor For Each Equipment} = \text{Market Rate Of Interest} + \text{Rate Of Depreciation For Each Equipment}^5
\]

8. \[
    \text{Annualized Additional Direct Investment Cost Of Each Equipment} = \text{Capital Recovery Factor Of Each Equipment} \times \text{Total Additional Direct Investment Cost Of Each Equipment}
\]

9. \[
    \text{Total Annualized Additional Direct Investment Cost Of All Equipment} = \text{Sum Of Annualized Additional Direct Investment Cost Of All Equipment Used the Interventions}
\]

10. \[
    \text{Annualized Additional Direct Costs Of Interventions} = \text{Total Annualized Additional Direct Investment Cost Of All Equipment} + \text{Annual Labor Costs For Intervention Implementation}^6
\]

### Avoided Medical Care Costs

11. \[
    \text{Total Annual Avoided Medical Care Costs} = [\text{Medical Care Costs Before Intervention (Acute Cases)} - \text{Medical Care Costs After Intervention (Acute Cases)}] + [\text{Medical Care Costs Before Intervention (Chronic Cases)} - \text{Medical Care Costs After Intervention (Chronic Cases)}]
\]

12. \[
    \text{Medical Care Costs Before Intervention (Acute)} = \text{Average Medical Care Cost Per Acute Case In 2002 Dollars} \times \text{Number Of Employees Suffering From Acute LBP Before Intervention}
\]

13. \[
    \text{Medical Care Costs After Intervention (Chronic)} = \text{Average Medical Care Cost Per Chronic Case In 2002 Dollars} \times \text{Number Of Employees Suffering From Chronic LBP Before Intervention}
\]

14. \[
    \text{Medical Care Costs After Intervention (Acute)} = \text{Medical Care Cost Per Case In 2002 Dollars} \times \text{Number Of Employees Suffering From Acute LBP After Intervention}
\]

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3 For example, we should take the price of an ergonomically approved adjustable chair and deduct from that the price of a traditional chair that was used originally. It is this additional cost of an adjustable chair that should be treated as equipment cost.

4 Direct costs should also include costs of operation and maintenance. We however, did not mention them in these equations because they were reported as negligible in all three case studies. Our questionnaire items presented in the appendix include them.

5 The depreciation for each type of equipment has been calculated by taking into account the life of the equipment and their salvage value by using the depreciation formula explained in the text.

6 For example this cost included all costs involved in training workers to use ergonomically designed equipments.
(15) Medical Care Costs After Intervention (Chronic) = Medical Care Cost Per Case In 2002 * Number Of Employees Suffering From Chronic LBP After Intervention

**Loss In Productivity Due To LBP**

(16) Avoided Productivity Losses Due To LBP = Reduction In The Value Of Lost Work Time Due To LBP + Reduction In Efficiency Due To LBP When Not On Leave

(17) Reduction In The Value Of Lost Work Time Due To LBP = Value Of Lost Work Time Due To Sick Leave Before Intervention - Value Of Lost Work Time Due To Sick Leave After Intervention

(18) Value Of Lost Work Time Due To Sick Leave Before Intervention = Number Of Missed Days Of Work Before Intervention * Wage Per Hour In $ Paid During Sick Leave Due To Back Pain * Number Of Work Hours Per Day

(19) Value Of Lost Work Time Due To Sick Leave After Intervention = Average Number Of Missed Days Of Work After Intervention * Wage Per Hour In $ Paid During Sick Leave Due To Back Pain * Number Of Work Hours Per Day

(20) Reduction In Efficiency Due To LBP When Not On Leave = Total Number Of Employees Suffering From LBP Without Leave * Number Of Days Of Duration Of LBP For Each Employee * Coefficient Of Loss In Productivity

(21) Coefficient Of Loss In Productivity In Dollars = Average Wage Rate – Adjusted Average Wage Rate Taking Into Account The Percentage Loss In Productivity

**Enhancement In Productivity**

(22) Annual Value Of Increase In Productivity Due To The Intervention = Number Of Workers Subjected To Intervention * Number Of Work Hours Per Week * Number Of Weeks Worked Per Year * Coefficient Of Productivity Gain Due To The Intervention

(23) Coefficient Of Gain In Productivity In Dollars = Adjusted Average Wage Rate Taking Into Account The Percentage Gain In Productivity - Average Wage Rate
Data Collection

A questionnaire targeted to solicit information that a company would be able to provide was developed based on the net-cost model and is presented in Table AI in the appendix. It includes questions regarding the nature of the intervention(s) for low back pain, and the number of employees suffering from back pain before and after the interventions. Pre- and post-intervention data was collected on the duration of back pain and/or disability (acute: 0-12 weeks; chronic: more than 12 weeks), number of missed days of work, and average wage of employees with back pain. Information on decreases in productivity (if any) due to back pain and increases in efficiency (if any) after the intervention was solicited.

Direct costs of the interventions including equipment costs, and any additional wages (including training costs) paid to implement the intervention were obtained. We are interested in the direct additional cost that is incurred due to the introduction of the intervention. Economists call this direct additional cost the marginal cost. In other words, if we are providing ergonomically approved adjustable chairs as an intervention to prevent LBP, we should take the price of an ergonomically approved adjustable chair and deduct from that the price of a traditional chair that was used originally. It is this additional cost of an adjustable chair that should be treated as equipment cost.

The capital recovery factor was determined for all purchased intervention equipment. The depreciation can be calculated with the help of the following formula:

\[ K = \sum d (1+ i)^{-a} + \phi \]

where:
- \( K \) = total investment
- \( D \) = depreciation
- \( I \) = interest rate
- \( a \) = service life of the equipment in years
- \( t \) = running time variable
- \( \phi \) = salvage value of the equipment

If one calculates the annual flat rate of depreciation based on the above formula, the depreciation rate \( d \) becomes smaller for equipment that has a longer useful life or has a high salvage value. The interest rate that is used to compute the capital recovery factor represents the long run opportunity cost of private capital (rate of return on private capital).

Medical care costs were determined from state-based cost tables of compensable low back pain cases [Webster et al., 1994]. The mean cost/case was used for acute/sub-acute cases, while the median cost/case was used for calculating medical care costs for chronic low back pain cases. Comparable data was obtained from the state Workers’ Compensation agency for the one company where insurance was administered through a state-operated fund. All costs were converted into 2002 dollars.

Companies that had implemented ergonomic interventions were found from the OSHA and Washington State “success stories” websites, from the National Safety Council, and from independent and university-based ergonomic consultants. Thirty-seven companies were contacted, and 22 were sent questionnaires. Four completed questionnaires were received. One of these companies did not have back pain cases; the company safety personnel stated that any incipient cases were perhaps prevented by ergonomic interventions.

Three companies not answering the questionnaire did not have adequate resources to fill out the questionnaire, while two companies sent descriptive information regarding ergonomic interventions and effectiveness. An additional company could not answer the questionnaire as structured since the back pain prevention intervention component could not be separated from their overall safety program.

RESULTS OF CASE STUDIES

The net-cost model was solved on an EXCEL spreadsheet using the data supplied by three companies. Questionnaire A1 presented in the appendix was filled out by the Companies and sent to the authors.

Case Study A

A 123-employee wood processing plant implemented ergonomic interventions for forklift, crane and machine operators, technicians, and utility/general production workers for a period of three years. A total of 115 employees were subjected to the interventions over a period of three years. After conducting ergonomic evaluations, engineering controls and workstation modifications were instituted. New equipment included adjustable chairs, conveyors, lift tables, anti-fatigue matting, grabbers and catwalks to minimize use of ladders. These costs are itemized in Table I. Since these different types of equipment were purchased in different years, all unit prices were adjusted to 2002 prices using the CPI index (2003) as depicted in row 5 of Table I. By deducting the costs of equipment that were purchased before the intervention, the additional costs of equipment were obtained (row 12 of Table I). All additional costs were annualized, by taking into account the capital recovery factor. The capital recovery factor for each type of equipment was obtained by taking the sum of the depreciation rate and a uniform rate of opportunity cost of capital of 7%. The depreciation rate for each equipment was determined by using the formula for depreciation cited in the earlier section, which takes into account the life of the equipment and its salvage value. The varying depreciation rates are shown in row 17 of Table I. The total additional annualized direct cost on equipment was $4838 as is evident from row 20 in Table I.

A physical therapist was hired to teach employees pre-shift exercises for prevention of
musculoskeletal disorders. The total direct costs of intervention on equipment as well as labor were $5338.

Employee reported symptoms identified low back pain. Before the interventions, there were six acute cases of LBP. After the interventions, no cases of LBP were reported. In other words, the effectiveness of the interventions in curing acute back pain was reported to be 100%. Hence, all of the medical care costs prior to the interventions that totaled $1010.00 (in 2002 dollars) were considered as avoided medical care costs. This resulted in a net annualized cost of interventions net of medical care costs as $4328.00.

The workers in this company did not report of any sick days due to Acute LBP. However, the company estimated a 15% loss in productivity due to LBP. We find this figure to be consistent with the average loss in productive time of 5.2/hrs per week for LBP [Stewart et al., 2003]. We assumed an average duration of acute LBP to be six weeks (30 working days). For the six workers, we estimated a value of lost work time due to lower efficiency as $2160. The computations were performed by adjusting the average wage rate to $8.50 (row 42 in Table I) to reflect the lower efficiency during that period. Hence the total avoided annual loss in productivity was $2160. This brought down the total annualized net-costs of intervention to $2168.00 and a net-cost of intervention per employee net of medical care costs and work time loss to $17.62.

However, one of the most beneficial effects of these interventions was reflected in an enhancement in productivity for all workers that were subjected to the interventions which was reported by the company official as 10%. The total gain in productivity estimated by our model was $79,040. We assumed that the current average wage rate of the worker represented a typical value of his marginal productivity. The net-cost after taking into account this enhancement was - $76,872 with the cost per employee at - $624.98. In other words, there was a total net savings of $76,872 for the company as a whole and it resulted in a savings of $625 per worker.
### Table I

**Estimation Of Annualized Net Economic Costs Of Ergonomic Interventions For Reducing Low Back Pain - Case Study A**

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<tr>
<td>23.</td>
<td>Annual Medical Care Costs In 2002 Dollars After Intervention</td>
<td>$0.00</td>
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<td>24.</td>
<td>Annual Medical Care Costs In 2002 Dollars Before Intervention (Row 27 + Row 30)</td>
<td>$1,010</td>
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<tr>
<td>25.</td>
<td>Number Of Employees Suffering From Acute Low Back Pain</td>
<td>6 Workers</td>
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<td>26.</td>
<td>Medical Care Cost Per Acute Case</td>
<td>$168.29</td>
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<tr>
<td>27.</td>
<td>Total Medical Care Cost For Acute Cases</td>
<td>$1,009.76</td>
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<tr>
<td>28.</td>
<td>Number Of Employees Suffering From Chronic Low Back Pain</td>
<td>0 Workers</td>
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<tr>
<td>29.</td>
<td>Medical Care Cost Per Chronic Case</td>
<td>$0.00</td>
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<tr>
<td>30.</td>
<td>Total Medical Care Cost For Chronic Cases</td>
<td>$0.00</td>
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<tr>
<td>31.</td>
<td>Total Avoided Annual Medical Care Costs (Row 24 – Row 23)</td>
<td>$1,010</td>
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<tr>
<td>32.</td>
<td>Net Cost Net Of Medical Care Costs (Row 22 – Row 31)</td>
<td>$4,328</td>
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<tr>
<td>33.</td>
<td>Value of Lost Work Time After Intervention</td>
<td>$0.00</td>
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<tr>
<td>34.</td>
<td>Value Of Lost Work Time Before Intervention Due To Lower Efficiency (Row 35 * Row 36 * Row 38 * Row 41)</td>
<td>$2,160</td>
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<tr>
<td>35.</td>
<td>Number Of Workers With Acute LBP Before Intervention</td>
<td>6 Workers</td>
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<tr>
<td>36.</td>
<td>Average Duration Of Illness</td>
<td>30 Days</td>
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<td>37.</td>
<td>Number Of Sick Days Due To LBP</td>
<td>0 Days</td>
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<tr>
<td>38.</td>
<td>Number Of Hrs/Day</td>
<td>8 Hours</td>
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<tr>
<td>39.</td>
<td>Reduced Efficiency</td>
<td>15 Percent</td>
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<tr>
<td>40.</td>
<td>Average Wage Rate Per Hour</td>
<td>$10.00</td>
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<tr>
<td>41.</td>
<td>Productivity Loss Per Injured Worker Per Hour (0.15 * Row 40)</td>
<td>$1.5</td>
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<tr>
<td>42.</td>
<td>Adjusted Wage Rate After Loss In Productivity By 15% (Row 40 – Row 41)</td>
<td>$8.50</td>
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<tr>
<td>43.</td>
<td>Total Avoided Annual Loss In Productivity (Row 34 – Row 33)</td>
<td>$2,160</td>
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<td>44.</td>
<td>Net Cost Net Of Medical Care Costs And Work Time Loss (Row 22 – Row 31 – Row 43)</td>
<td>$2,168</td>
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<tr>
<td>45.</td>
<td>Cost Of Intervention Per Employee Net Of Medical Care Costs And Work Time Loss (Row 44 ÷ Row 52)</td>
<td>$17.62</td>
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<tr>
<td><strong>46. Enhancement In Productivity For All Workers Subjected To Intervention</strong></td>
<td>10%</td>
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<tr>
<td><strong>47. Productivity Gain Per Worker (0.10 * Row 40)</strong></td>
<td>$1.00</td>
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<tr>
<td><strong>48. Adjusted Wage Rate After Increases In Productivity By 10% (Row 40 + Row 47)</strong></td>
<td>$11.00</td>
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<tr>
<td><strong>49. Average Number Of Workers Subjected To Intervention</strong></td>
<td>38 Workers</td>
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<tr>
<td><strong>50. Total Annual Gain In Productivity (52 * 40 * Row 47 * Row 48)</strong></td>
<td>$79,040</td>
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<tr>
<td><strong>52. Total Number of Employees</strong></td>
<td>123 Workers</td>
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<tr>
<td><strong>53. Annualized Net-Cost Taking Into Account Enhancement In Productivity Per Employee (Row 51 + Row 52)</strong></td>
<td>-$625</td>
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<tr>
<td><strong>54. Annualized Cost Savings per Worker (Abs. Value of Row 53)</strong></td>
<td>$625</td>
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<tr>
<td><strong>55. Benefit–to–Cost Ratio</strong></td>
<td>15.40</td>
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</table>

**Notes:**

- Labor Costs included training Costs On Physical Therapist For Pre-shift Exercise and Stretching.
- The market rate of interest as a proxy for the opportunity cost of capital was taken as 7 percent.
- Average Duration of Illness for acute and sub acute LBP has been taken as 6 weeks (30 working days).
- The effectiveness of the interventions was reported to be 100%.
Case Study B

A major automotive supplier with 637 workers has instituted an office ergonomics program for the past twelve years. Employees affected included secretaries, engineers, engineering technicians, managers, and salespersons. With regard to reducing back discomfort, lumbar pads and backrests were made available to employees (Table II). Back school workshops were also conducted.

In the year prior to the interventions, 41 employees complained of back pain or discomfort. Of these, three cases were categorized as acute (0-6 weeks in duration). The average number of missed days reported by the company due to LBP was 20 days. The remaining 38 cases were relieved the same day as the intervention. That is, no further complaints were received from these individuals. In the twelve years since the interventions were first implemented, twelve workers reported back pain. But, no sick leave was taken due to the discomfort. Of these, two were acute cases, and ten were relieved upon intervention.

Medical care costs totaled $286.74 prior to the intervention, and $191.16 after the intervention. Hence, the net cost for medical care was $95.58. Lost work time due to sick leave before the intervention was $4800 (Row 40 in Table II). The company estimated a productivity loss of 20% for employees in pain or discomfort. A total loss in work time due to reduced efficiency for employees not on sick leave was $3984.00 (row 56). A 5% productivity improvement was reported, resulting from the ergonomic interventions. The total gain in productivity was estimated as $62,400 for the 20 employees that were subjected to the interventions. The estimated net-cost after taking into account this enhancement was -$70,440 with the cost per employee at -$110.58. In other words, the ergonomic interventions resulted in an estimated cost savings of $110.58 per employee.

---

It was impossible to separate this productivity gain from other ergo improvements for upper extremity.
### Table II

**Estimation Of Annualized Net Economic Costs Of Ergonomic Interventions For Reducing Low Back Pain - Case Study B**

<table>
<thead>
<tr>
<th>Direct Costs Of Investments On Interventions</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Type Of Equipment</td>
<td>Lumbar Pads</td>
<td>Back Rests</td>
<td></td>
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</tr>
<tr>
<td>2. Year Purchased</td>
<td>1997</td>
<td>1997</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Unit Price Of Equipment Purchased After Intervention</td>
<td>$20.00</td>
<td>$25.00</td>
<td></td>
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</tr>
<tr>
<td>4. Quantity Of Current Equipment Purchased</td>
<td>80</td>
<td>24</td>
<td></td>
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</tr>
<tr>
<td>5. Unit Price Of Item Adjusted To 2002 (Using CPI)</td>
<td>$22.42</td>
<td>$28.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Value Of Equipment Purchased After Intervention In 2002 Prices (Row 4 * Row 5)</td>
<td>$1793.40</td>
<td>$672.52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Purchase Year For Prior Equipment</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Unit Price Of Prior Equipment Purchased</td>
<td>$0.00</td>
<td>$0.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Quantity Of Prior Equipment Purchased</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Unit Price Of Prior Equipment Adjusted To 2002 (Using CPI)</td>
<td>$0.00</td>
<td></td>
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<tr>
<td>11. Value Of Equipment Purchased Before Intervention In 2002 Prices (Row 9 * Row 10)</td>
<td>$0.00</td>
<td>$0.00</td>
<td></td>
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<tr>
<td>12. Additional Direct Investment Cost In 2002 $ (Row 6 – Row 11)</td>
<td>$1793.40</td>
<td>$672.52</td>
<td></td>
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<tr>
<td>13. Expected Life Of Equipment (Years)</td>
<td>10</td>
<td>10</td>
<td></td>
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<tr>
<td>14. Salvage Value</td>
<td>$0.00</td>
<td>$0.00</td>
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<tr>
<td>15. Net Of Savage Value (Row 12 – Row 15)</td>
<td>$1793.40</td>
<td>$672.52</td>
<td></td>
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<tr>
<td>16. Depreciation (Using Formula)</td>
<td>$121.309</td>
<td>$45.49</td>
<td></td>
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<tr>
<td>17. Rate Of Depreciation (Row 16 ÷ Row 15)</td>
<td>0.0676</td>
<td>0.0676</td>
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<tr>
<td>18. Capital Recovery Factor (Interest Rate 7% + Row 17)</td>
<td>0.14</td>
<td>0.14</td>
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<tr>
<td>19. Annualized Direct Investment Cost Of Equipment (Row 15 * Row 12)</td>
<td>$246.85</td>
<td>$92.57</td>
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<tr>
<td>20. Total Annualized Direct Investment Cost Of Equipment (Row 19: Σ(Columns 2 and 3))</td>
<td>$339.42</td>
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<tr>
<td>21. Other Costs For Implementing Intervention In 2002 Dollars</td>
<td>$500.00</td>
<td></td>
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<tr>
<td>22. Total Direct Cost Of Intervention Including Labor Costs (Row 20 + Row 21)</td>
<td>$839.42</td>
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</tr>
</tbody>
</table>

**Medical Care Costs**

| 23. Annual Medical Care Costs In 2002 Dollars After Intervention (Row 26) | $191.16 |
| 24. Number Of Workers Suffering From Acute Low Back Pain | 2 Workers |
| 25. Medical Care Cost Per Acute Case | $95.58 |
| 26. Total Medical Care Cost For Acute Cases | $191.16 |
| 27. Annual Medical Care Costs In 2002 Dollars Before Intervention (Row 30) | $286.74 |
| 28. Number Of Workers Suffering From Acute Low Back Pain | 3 Workers |
| 29. Medical Care Cost Per Acute Case | $95.58 |
| 30. Total Medical Care Cost For Acute Cases | $286.74 |
| 31. Total Avoided Annual Medical Care Costs (Row 27 – Row 23) | $95.58 |
Lahiri, S, et al - Estimation of net-costs for prevention of occupational low back pain: three case studies from the US

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<p>| | |</p>
<table>
<thead>
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<tbody>
<tr>
<td>32. Net Cost Net Of Medical Care Costs (Row 22 – Row 31)</td>
<td>$743.84</td>
</tr>
<tr>
<td>33. Cost Of Intervention Net Of Medical Care Costs Per Employee (Row 32 ÷ Row 66)</td>
<td>$1.17</td>
</tr>
<tr>
<td>34. Value Of Lost Work Time Due To Sick Leave After Intervention</td>
<td>$0.00</td>
</tr>
<tr>
<td>35. Number Of Missed Days Of Work</td>
<td>0 Days</td>
</tr>
<tr>
<td>36. Value Of Lost Work Time Due To Sick Leave Before Intervention (Row 37 * Row 38 * Row 39)</td>
<td>$4,800.00</td>
</tr>
<tr>
<td>37. Number Of Missed Days Of Work</td>
<td>20 Days</td>
</tr>
<tr>
<td>38. Average Wage Rate</td>
<td>$30.00</td>
</tr>
<tr>
<td>39. Number Of Hrs/Day</td>
<td>8 Hours</td>
</tr>
<tr>
<td>40. Total Avoided Annual Value Of Lost Work Time Due To Sick Leave (Row 36 – Row 34)</td>
<td>$4,800.00</td>
</tr>
<tr>
<td>41. Value Of Lost Work Time Before Intervention Due To Lower Efficiency</td>
<td></td>
</tr>
<tr>
<td>42. Total Number Of Days Of Reduced Efficiency Due To Acute LBP For All Workers (See Notes Below)</td>
<td>45 Days</td>
</tr>
<tr>
<td>43. Number Of Hours Per Work Day</td>
<td>8 Hours</td>
</tr>
<tr>
<td>44. Reduced Efficiency</td>
<td>20 Percent</td>
</tr>
<tr>
<td>45. Average Wage Rate Per Hour</td>
<td>$30.00</td>
</tr>
<tr>
<td>46. Productivity Loss Per Injured Worker Per Hour (0.2 * Row 45)</td>
<td>$6.00</td>
</tr>
<tr>
<td>47. Adjusted Wage Rate After Loss In Productivity By 20% (Row 45 – Row 46)</td>
<td>$24.00</td>
</tr>
<tr>
<td>48. Total Loss Work Time Due To Reduced Efficiency From Acute LBP (Row 42 * Row 43 * Row 46)</td>
<td>$2160.00</td>
</tr>
<tr>
<td>49. Total Number Of Days Of Reduced Efficiency Due To Sub Acute LBP For All Workers (See Notes Below)</td>
<td>38 Days</td>
</tr>
<tr>
<td>50. Reduced Efficiency</td>
<td>20 Percent</td>
</tr>
<tr>
<td>51. Number Of Hours Per Work Day</td>
<td>8 Hours</td>
</tr>
<tr>
<td>52. Average Wage Rate Per Hour</td>
<td>$30.00</td>
</tr>
<tr>
<td>53. Productivity Loss Per Injured Worker Per Hour (0.2 * Row 52)</td>
<td>$6.00</td>
</tr>
<tr>
<td>54. Adjusted Wage Rate After Loss In Productivity By 20% (Row 52 – Row 53)</td>
<td>$24.00</td>
</tr>
<tr>
<td>55. Total Loss Work Time Due To Reduced Efficiency From Sub Acute LBP (Row 49 * Row 51 * Row 53)</td>
<td>$1824.00</td>
</tr>
<tr>
<td>56. Total Value Of Lost Productivity Due To Reduced Efficiency (Row 48 + Row 55)</td>
<td>$3984.00</td>
</tr>
<tr>
<td>57. Net Cost Net Of Medical Care Costs And Work Time Loss (Row 22 – Row 31 – Row 40 – Row 56)</td>
<td>-$8040</td>
</tr>
<tr>
<td>58. Total Number Of Employees</td>
<td>637 Employees</td>
</tr>
<tr>
<td>59. Cost Of Intervention Per Employee Net Of Medical Care Costs And Work Time Loss (Row 57 ÷ Row 58)</td>
<td>-$12.62</td>
</tr>
</tbody>
</table>

Enhancement in Productivity

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>60. Enhancement In Productivity For All Workers Subjected To Intervention</td>
<td>5%</td>
</tr>
<tr>
<td>61. Productivity Gain Per Worker (0.05 * Row 52)</td>
<td>$1.50</td>
</tr>
<tr>
<td>62. Adjusted Wage Rate After Increases In Productivity By 5% (Row 52 + Row 61)</td>
<td>$31.50</td>
</tr>
<tr>
<td>63. Average Number Of Workers Subjected To Intervention</td>
<td>20 Workers</td>
</tr>
<tr>
<td>64. Total Annual Gain In Productivity (52 weeks * 40 hours per week * Row 60)</td>
<td>$62,400.00</td>
</tr>
<tr>
<td>66. Total Number Of Employees</td>
<td>637 Employees</td>
</tr>
</tbody>
</table>
Lahiri, S, et al - Estimation of net-costs for prevention of occupational low back pain: three case studies from the US

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<table>
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</thead>
<tbody>
<tr>
<td>67.</td>
<td>Annualized Net-Cost Taking Into Account Enhancement In Productivity Per Employee (Row 65 ÷ Row 66)</td>
</tr>
<tr>
<td>68.</td>
<td>Cost Savings Per Worker</td>
</tr>
<tr>
<td>69.</td>
<td>Benefit-to-Cost Ratio</td>
</tr>
</tbody>
</table>

Notes:
There was a productivity loss of 20% for all employees who are in pain or discomfort. There were 3 workers who had on average symptoms from 0-6 weeks. For estimation purposes we have taken the mid point of duration of illness to be 3 weeks (15 working days). The other 38 workers had symptoms only for 1 day.

There are 41 workers who were subject to back pain in the most recent year. However, the number of workers who were subject to back pain interventions on an average over the past 12 years is 20.
Case Study C

During a four-year time period, a 1500 worker automobile and truck body plant instituted ergonomic interventions in various assembly lines. These interventions included a number of engineering controls. Ergonomic dollies used for transporting cabs in the truck cab trim sub-assembly line were re-designed. The increased height of the dolly (with retractable step added for safety) reduced the amount of bending required in assembly tasks [Council, 2003]. In other lines, lift and tilt tables were installed, allowing adjustment of workstation heights. Mechanical lift assists and various platforms and risers reduced loads and awkward back postures of employees. Annualized equipment and labor cost was $512,657 (row 22 of Table III).

In the three years prior to the intervention, an annual average of 11.3 employees suffered from short duration back pain, and on average 4 cases were chronic. The average annual number of missed days of work due to back pain was 693. In the three years following the implementation of the interventions, back pain was greatly reduced. An annual average of 3.3 acute cases occurred, with an annual average of one sick day.

Avoided medical care costs due to the intervention were estimated at $16,280 (row 37 of Table III), while avoided sick leave costs were $121,792 (row 47 of Table III). The enhancement in productivity was reported at 40%. The company reported that after intervention the time required to produce 1 unit got reduced from 80 hours to 57 hours. The total gain in productivity was $2,708,992 (row 54 of Table III). The net-cost after taking into account this enhancement was -$2,334,409 with the cost per employee at -$1556. In other words, estimated cost savings per worker was $1556.
### Table III

**Estimation Of Annualized Net Economic Costs Of Ergonomic Interventions For Reducing Low Back Pain - Case Study C**

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<tbody>
<tr>
<td><strong>Direct Costs Of Investments On Interventions</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Type Of Equipment</td>
<td>Dolly’s</td>
<td>Lift / Tilt Tables</td>
<td>Risers</td>
<td>Lift Assist</td>
<td>Marker Light Platform</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Unit Price Of Equipment Purchased After Intervention</td>
<td>$1,917.00</td>
<td>$3,000.00</td>
<td>$300.00</td>
<td>$15,000.00</td>
<td>$1,000.00</td>
<td></td>
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<tr>
<td>4. Quantity Of Current Equipment Purchased</td>
<td>85</td>
<td>12</td>
<td>47</td>
<td>9</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Unit Price Of Item Adjusted To 2002 dollars (using CPI)</td>
<td>$2,002.72</td>
<td>$3,134.15</td>
<td>$313.41</td>
<td>$15,670.73</td>
<td>$1,044.72</td>
<td></td>
<td></td>
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<tr>
<td>6. Value Of Equipment Purchased After Intervention In 2002 Prices (Row 4 * Row 5)</td>
<td>$17,0231.16</td>
<td>$3,7609.76</td>
<td>$1,4730.49</td>
<td>$14,1036.59</td>
<td>$1,044.72</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Purchase Year For Prior Equipment</td>
<td>1979</td>
<td>0</td>
<td>1979</td>
<td>1979</td>
<td>1979</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Unit Price Of Prior Equipment Purchased</td>
<td>$1,000.00</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$2,000.00</td>
<td>$200.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Quantity Of Prior Equipment Purchased</td>
<td>85</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>10. Unit Price Of Prior Equipment Adjusted To 2002 (using CPI)</td>
<td>$2,477.96</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$4,955.92</td>
<td>$495.59</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Value Of Equipment Purchased Before Intervention In 2002 Prices (Row 9 * Row 10)</td>
<td>$21,0626.72</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$19,823.69</td>
<td>$495.59</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Additional Direct Investment Cost (In 2002 $) (Row 6 - Row 11)</td>
<td>$-40,395.56</td>
<td>$37,609.76</td>
<td>$14,730.49</td>
<td>$12,1212.89</td>
<td>$549.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Expected Life Of Equipment (Years)</td>
<td>25</td>
<td>10</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Salvage Value</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$0.00</td>
<td></td>
<td></td>
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<tr>
<td>15. Net Of Savage Value (Row 12 – Row 14)</td>
<td>$-40,395.56</td>
<td>$37,609.76</td>
<td>$14,730.49</td>
<td>$12,1212.89</td>
<td>$549.12</td>
<td></td>
<td></td>
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<tr>
<td>16. Depreciation (using formula)</td>
<td>$-596.89</td>
<td>$2544.02</td>
<td>$145.74</td>
<td>$1199.26</td>
<td>$5.43</td>
<td></td>
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<tr>
<td>17. Rate Of Depreciation ( Row 16 ÷ Row 15)</td>
<td>0.0148</td>
<td>0.0676</td>
<td>0.0099</td>
<td>0.0099</td>
<td>0.0099</td>
<td></td>
<td></td>
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<tr>
<td>18. Capital Recovery Factor (Interest Rate 7% + Rate Of Depreciation)</td>
<td>0.0848</td>
<td>0.1376</td>
<td>0.0799</td>
<td>0.0799</td>
<td>0.0799</td>
<td></td>
<td></td>
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<tr>
<td>19. Annualized Additional Direct Investment Cost Of Equipment (Row18* Row12)</td>
<td>$-3424.58</td>
<td>$5176.70</td>
<td>$1176.88</td>
<td>$9684.16</td>
<td>$43.87</td>
<td></td>
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<tr>
<td>20. Total Annualized Direct Investment Cost Of Equipment (Row 19: Σ(Columns 2 – 6))</td>
<td>$12,657</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>21. Labor Costs For Implementing Intervention In 2002 Dollars</td>
<td>$500,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22. Total Direct Cost Of Intervention Including Labor Costs (Row 20 + Row 21)</td>
<td>$512,657</td>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

**Medical Care Costs**
<p>| | | | | | | | |</p>
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<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>23. <strong>Annual Medical Care Costs in 2002 Dollars After Intervention (Row 26 + Row 29)</strong></td>
<td>$1,462</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24. Number of Employees Suffering From Acute Low Back Pain</td>
<td>3.33</td>
<td>Workers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25. Medical Care Cost Per Acute Case in 2002 dollars</td>
<td>$438.57</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26. Total Medical Care Cost For Acute Cases (Row 24 * Row 25)</td>
<td>$1,461.90</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>27. Number of Employees Suffering From Chronic Low Back Pain</td>
<td>0.00</td>
<td>Workers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28. Medical Care Cost Per Chronic Case</td>
<td>$3,193.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29. Total Medical Care Cost For Chronic Cases (Row 27 * Row 28)</td>
<td>$0.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>30. <strong>Annual Medical Care Costs in 2002 Dollars Before Intervention (Row 33 + Row 36)</strong></td>
<td>$17,742</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31. Average Number of Employees Suffering From Acute Low Back Pain</td>
<td>11.33</td>
<td>Workers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32. Medical Care Cost Per Acute Case</td>
<td>$438.57</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33. Total Medical Care Cost For Acute Cases (Row 31 * Row 32)</td>
<td>$4,969.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34. Average Number of Employees Suffering From Chronic Low Back Pain</td>
<td>4</td>
<td>Workers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35. Medical Care Cost Per Chronic Case</td>
<td>$3,193.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36. Total Medical Care Cost For Chronic Cases (Row 34 * Row 35)</td>
<td>$12,773.01</td>
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</table>

**Total Annual Avoided Medical Care Costs (Row 30 – Row 23)**: $16,280

**Net Cost Net Of Medical Care Costs (Row 22 – Row 37)**: $496,377

**Value Of Lost Work Time After Intervention Due To Sick Leave (Row 40 * Row 41 * Row 42)**: $176

**Value Of Lost Work Time Before Intervention Due To Sick Leave (Row 44 * Row 45 * Row 46)**: $121,968
<p>| | |</p>
<table>
<thead>
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</tr>
</thead>
<tbody>
<tr>
<td>47. Total Avoided Annual Loss in Work time Due to Sick Leave (Row 43-Row 39)</td>
<td>$121,792</td>
</tr>
<tr>
<td>48. Net Cost, Net Of Medical Care Costs And Work Time Loss (Row 22 – Row 37 – Row 47)</td>
<td>$374,585</td>
</tr>
<tr>
<td>49. Cost Of Intervention Per Employee Net Of Medical Care Costs And Work Time Loss (Row 48 – Row 56)</td>
<td>$250</td>
</tr>
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</table>

### Enhancement in Productivity

<p>| | |</p>
<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>50. Enhancement In Productivity For All Workers Subjected To Intervention</td>
<td>40%</td>
</tr>
<tr>
<td>51. Productivity Gain Per Worker (0.40 * Row 46)</td>
<td>$8.8</td>
</tr>
<tr>
<td>52. Adjusted Wage Rate After Increases In Productivity By 40% (Row 46 + Row 51)</td>
<td>$30.80</td>
</tr>
<tr>
<td>53. Number Of Workers Subjected to Intervention</td>
<td>148 Workers</td>
</tr>
<tr>
<td>54. Total Annual Gain In Productivity (52 weeks * 40 hours per week * Row 51 * Row 53)</td>
<td>$2,708,992</td>
</tr>
<tr>
<td>56. Total Number of Employees</td>
<td>1500 Employees</td>
</tr>
<tr>
<td>57. Annualized Net-Cost Taking Into Account Enhancement In Productivity Per Employee (Row 55 + Row 56)</td>
<td>-$1556</td>
</tr>
<tr>
<td>58. Cost Savings Per Worker (Abs. Value Of Row 57)</td>
<td>$1556</td>
</tr>
<tr>
<td>59. Benefit-to-Cost Ratio</td>
<td>5.5</td>
</tr>
</tbody>
</table>

### Notes:

- The labor costs include all costs related to the implementation of the intervention.
- The market rate of interest as a proxy for the opportunity cost of capital was taken as 7 percent.
- After the intervention productivity for all workers increased from 80 hours per unit to 57 hours per unit.
Sensitivity Analysis
Since there is considerable uncertainty in the data and parameters that we used to estimate the net-cost of interventions, we performed sensitivity analysis on the results on cost savings with respect to two crucial parameters: i) interest rate to represent the long run opportunity cost of capital to estimate the annualized investment costs of interventions; ii) productivity enhancement coefficient that essentially represents the advanced technological aspects of mainly engineering control interventions. We perturbed the above two parameters, interest rate (5% to 10%) and productivity enhancement coefficients (5% to 25% for case studies A and B and 10% to 50% for case study C) and solved the model with the perturbed values of these parameters.

The results of the sensitivity analysis are reported in Figures 1 through 9. We find that both interest rates and productivity enhancements are critical variables in determining the net costs of the interventions. Sensitivity analyses show that the direction of the net savings results is robust with respect to changes in these parameters although their magnitudes vary. In other words, the cost savings remain positive in spite of our different assumptions with respect to varying rates of interest and productivity. However, the sensitivity results presented in the relevant figures show that the variability in net-costs is much more pronounced with respect to productivity improvements compared to interest rate changes. The annual cost savings almost double with an increase in productivity by 5 percentage points. However, when the borrowing costs double, the cost savings are reduced marginally. Hence, the results of the case studies clearly reveal that the productivity enhancement characteristic of the interventions is a very crucial component in making these investments on interventions profitable for the company.

Figures 1-2, 4-5 and 7-8 show the variability in direct costs of investment and cost savings at different assumed rates of interest for case studies A, B and C respectively. Figures 3, 6 and 9 show the wide variability in cost savings for the company as a whole for the three different case studies at alternative rates of improvement in the productivity coefficient for those workers who were subjected to ergonomic interventions.
Figure 1: Annualized Direct Cost of Investment at Alternative Market Rates of Interest: Case Study A

<table>
<thead>
<tr>
<th>Interest Rates (%)</th>
<th>4000</th>
<th>4500</th>
<th>5000</th>
<th>5500</th>
<th>6000</th>
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<tbody>
<tr>
<td>5.00</td>
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<td>6.00</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>7.00</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>8.00</td>
<td></td>
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<tr>
<td>9.00</td>
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<td>10.00</td>
<td></td>
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</tbody>
</table>
Figure 2: Cost Savings At Alternative Market Rates Of Interest:
Case Study A

<table>
<thead>
<tr>
<th>Interest Rate (%)</th>
<th>Cost Savings In $1000</th>
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<tbody>
<tr>
<td>5.00</td>
<td>77.4</td>
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<td>6.00</td>
<td>77.3</td>
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<tr>
<td>7.00</td>
<td>77.2</td>
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<tr>
<td>8.00</td>
<td>77.0</td>
</tr>
<tr>
<td>9.00</td>
<td>76.8</td>
</tr>
<tr>
<td>10.00</td>
<td>76.6</td>
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</tbody>
</table>
Figure 3: Cost Savings At Alternative Rates Of Enhancement In Productivity: Case Study A
Figure 4: Annualized Direct Cost Of Investment At Alternative Market Rates Of Interest: Case Study B
Figure 5: Cost Savings At Alternative Market Rates Of Interest: Case Study B

Cost Savings in $1000

Interest Rate %

5.00 6.00 7.00 8.00 9.00 10.00
Figure 6: Cost Savings at Alternative Rates Of Enhancement In Productivity: Case Study B

Cost Savings In $1000

% Enhancement In Productivity

5 10 15 20 25

5 10 15 20 25

350

300

250

200

150

100

50

50

100

150

200

250

300

350
Figure 7: Annualized Direct Cost of Investment at Alternative Market Rates of Interest: Case Study C

<table>
<thead>
<tr>
<th>Interest Rate (%)</th>
<th>Annualized Direct Cost of Investment in $</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>10,000</td>
</tr>
<tr>
<td>6</td>
<td>11,000</td>
</tr>
<tr>
<td>7</td>
<td>12,500</td>
</tr>
<tr>
<td>8</td>
<td>13,000</td>
</tr>
<tr>
<td>9</td>
<td>14,000</td>
</tr>
<tr>
<td>10</td>
<td>17,000</td>
</tr>
</tbody>
</table>
Figure 8: Cost Savings At Alternative Market Rates of Interest: Case Study C
Figure 9: Cost Savings at Alternative Rates of Enhancement in Productivity: Case Study C
DISCUSSION AND CONCLUSION

Our study provides a simple transparent framework to estimate the net-costs of investments on ergonomic interventions at the company level to reduce occupational morbidity. It illustrates the framework with three case studies. The particular formulation of the model was based on several other existing cost benefit frameworks that are available in the literature and was adapted to the data that were readily made available by three companies that had introduced such interventions over a number of years.

We are not aware of any study of ergonomic interventions that derive net-costs, hence our results are not directly comparable with other studies. For comparability of our study with other cost-benefit analyses, we calculated a benefit-to-cost ratios for each of the case studies and it ranges from 5.5 (Case study C) to 84 (Case Study B) and a ratio of 15 for case study A (Tables I-III).

In terms of cost-benefit analysis, our results compare favorably with other published results. For instance, the Upjohn Institute study [DeRango et al., 2003] obtained a benefit-to-cost ratio for chair-with-training intervention of 25 based on a longitudinal, quasi-experimental design field study of office workers. The results from the econometric study of participatory ergonomics [Lanoie et al., 1996] for packers at a warehouse of the Society des Alcoholes du Quebec in Quebec City also reports that the program was profitable for the company. Consistent with our negative net-costs of ergonomic interventions are the four case studies [Kemmlert, 1996] that evaluate the costs of ergonomic improvements. These studies estimated gains from ergonomic improvements and reported that Swedish companies achieved a pay-back period for the investment between 1 to 4 months. A pay back period of less than one year would imply negative net-costs according to our model. The cost-benefit analysis study of ergonomics programs for two case studies in the manufacturing sector in Australia [Oxenburg, 1997] also reports similar payback periods of less than 1 year for workplace interventions, hence lends support to the results of our study. The back injury and cost data of both the control and intervention groups before and after a one year intervention program conducted in a northern California county in 1989-90 showed a net benefit of introducing back injury prevention program to be $161,108 with a 179 percent return on investment [Shi, 1993].

Our analysis throws considerable light on a number of important policy issues. Our net- cost estimates for the three case studies consistently show that ergonomic interventions applied appropriately can result in substantial cost savings for the companies. 9 Although we do not like to generalize on the basis of three case studies, our analyses show that it might be in the economic interest of the management to take a more active role to prevent back pain.

Results of our analysis also reveal that the greatest economic savings to employers come from the improvement in productivity that result from the advanced technological design of the ergonomic interventions. We find in the literature that improvements in ergonomics often result in improvements in productivity (and vice versa). In fact, greater output per worker is often a consequence of ergonomic interventions, whether through individual workstation re-design, or through implementing engineering controls at a more macro level [Hendrick, 1996, 2003]. Ergonomic improvements to transportation equipment was successful in the South African forestry industry [Hendrick, 1996]. Although these improvements cost $300 per unit, it also resulted in an increase in productivity of $826 per unit. Ergonomic improvements to the loading/unloading processes resulted in higher rates of sugar cane transport [Hendrick, 2003]. In an Indonesian sugar factory, ergonomic interventions with a combination of other measures led to an enhancement in productivity [Manuaba, 1995].

While we have not considered the costs of back pain interventions from a societal point of view, we need to keep in mind that the productivity enhancement characteristics of the interventions might result in lay-offs and hurt the workers. In other words, comprehensive cost estimates from the society’s point of view need to include retraining (and other related costs – placement, mobility allowances) costs for the displaced workers as well. Not using the interventions to avert lay-offs is not a viable alternative because non-use of interventions would imply more injuries for the workers and the companies with similar unfavorable consequences for both.

In our attempts to gather useful cost information, we have found that the retrospective gathering of cost data, even on interventions deemed effective by corporate innovators, proved to be extremely difficult. Although they supported the idea of our study, many company officials indicated that the cost of developing such data retrospectively was prohibitive.

We know that the magnitude of avoidable costs essentially depends on the degree of effectiveness of the interventions. Since our case studies are based primarily on pre- and post-intervention observational studies, there remains considerable uncertainty in our estimates of avoidable costs. Collection of effectiveness data with the help of prospective studies would help in mitigating these effects of uncertainty in our estimates.

Hence we have concluded that it is essential to incorporate a protocol for collecting cost and effectiveness data in the standard operating procedures of ergonomists and companies introducing such innovations. A simple questionnaire incorporating the important aspects of the net-cost model is presented in Table A1 in the Appendix and the net-cost model can be solved using an excel spreadsheet. It is our hope that prospective studies incorporating this questionnaire or an adapted version of it may be used to more completely ascertain the net-costs of ergonomic interventions. In the near future, we aim to validate the net-cost model for the monitoring and reporting.

9 We tried to omit ergonomic improvements targeted exclusively to the upper extremity (such as wrist rests in the office setting) from our cost estimates. However, certain interventions such as general ergonomics training are applied to both lower and upper extremities. Hence, certain costs attributed to low back pain prevention may be over-estimated.
of such data in a variety of industrial settings and in countries at various stages of economic development. Currently we are working with our partners in India and Brazil to pilot this approach.

DISCLAIMER
The views expressed in this article are those of the authors and do not necessarily reflect the position of the World Health Organization.

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APPENDIX

The ergonomic intervention questionnaire for the companies used in our survey is presented below in Table AI.

**TABLE AI. Ergonomic Intervention Questionnaire**

This questionnaire has been developed by a research team at the University of Massachusetts Lowell. This team at UMASS Lowell is trying to develop estimates of Net-Costs of interventions to reduce work related back pain for select sectors of the economy under the sponsorship of the World Health Organization. As an industry leader, we would be very grateful if you would kindly fill in the following questionnaire. The purpose of the survey is purely academic. The information you provide will be held in strict confidence and will be used for research purposes only.

1. Organization:_____________ 2. Industry Title:_____________ 3. SIC code:_____________

4. Specific categories of low back pain interventions (please list):_________________________________

Our model will be based on annualized figures. We realize that your available statistics may take into account several years of data. Please fill in the appropriate time period that your statistics cover (in years or months) so that we can convert them into annual estimates.

5. Year(s) low back pain interventions were implemented (Number of years in dates e.g. 2000-2002): ____________

6. Number of employees that were subjected to the intervention (in each of these years): ______________

7. Were there any other interventions that were applied to prevent low back pain but not mentioned above? _______

**Characteristics of Workers with Low Back Pain** - We are interested in the type of work done by those employees who have suffered from low back pain and in the number of cases of low back pain in order to estimate the effectiveness of the interventions applied.

There are several different ways of specifying low back pain. What are the criteria you will be using to answer the following questions? (Examples of criteria include: employee reported symptoms of low back pain, employee had restricted duty, employee missed at least day of work due to low back pain, employee had an OSHA recordable incident, etc.)

8. What are the criteria for low back pain that you are using to fill out this questionnaire? ______________________

9. Please list the job title of each low back pain sufferer before and after the intervention:

   B: before the intervention, A: after the intervention,

<table>
<thead>
<tr>
<th>Job Title</th>
<th>BA: both before and after</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Our model will be based on annualized figures. We realize that your available statistics may take into account several years of data. Please fill in the appropriate time period that your statistics cover (in years or months).

10. Number of employees per year that suffered from low back pain prior to the intervention:

<table>
<thead>
<tr>
<th>Year</th>
<th>Nature of Back Pain</th>
<th>Number of employees</th>
<th>Number of missed days of work</th>
<th>Average Wage Of these employees</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Acute /Chronic</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: Acute Cases (0-12 weeks duration of pain and/or disability)
Chronic Cases (more than 12 weeks duration of pain and/or disability)

11. Number of employees per year that suffered from low back pain after the intervention:

<table>
<thead>
<tr>
<th>Year</th>
<th>Nature of Back Pain</th>
<th>Number of employees</th>
<th>Number of missed days of work</th>
<th>Average Wage Of these employees</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Acute /Chronic</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

12. Did you observe any loss in productivity due to lost work time (clinical visits, pain, fatigue etc.) even when the
worker did not miss the entire day of work? Yes/No
13. If the answer is “yes”, to the above question, what would be the average percentage of lost work time (hours / injured worker) or percentage decrease in efficiency per worker during the duration of their illness? ____________

14. Did you observe an increase in productivity per worker in the entire workforce (even those without prior back pain) simply due to the implementation of the ergonomic intervention? Yes/No
   If so, what was the percentage increase in efficiency per worker subjected to the intervention? ____________

**Direct Costs of Intervention**

We are interested in learning about the costs incurred by the company to apply the above intervention. We are assuming that this cost consisted of two components: equipment cost and cost of additional labor. We have formulated the following questions to get an estimate of the direct cost of applying the above-mentioned intervention to prevent low back pain.

15. Was there any equipment used in the low back pain intervention? *Yes or No*

16. If so, please list the types of equipment (lifts, adjustable chairs, etc.) that were used in the intervention:

<table>
<thead>
<tr>
<th>Type of equipment</th>
<th># Pieces required</th>
<th>Price per unit</th>
<th>Year purchased</th>
<th>Total equipment cost</th>
<th>Expected life of equipment</th>
<th>Total annual operating cost</th>
<th>Total maintenance cost</th>
</tr>
</thead>
</table>

17. If similar equipment was being purchased before the application of the Intervention, what was the price? (For example, if ergonomically designed adjustable chairs are now being purchased, what were the prices of the chairs that were being purchased before the intervention?)

<table>
<thead>
<tr>
<th>Type of equipment</th>
<th># Pieces required</th>
<th>Price per unit</th>
<th>Year purchased</th>
<th>Total equipment cost</th>
<th>Expected life of equipment</th>
<th>Total annual operating cost</th>
<th>Total maintenance cost</th>
</tr>
</thead>
</table>

18. What were the total annual additional wages/salaries paid for implementing the intervention? ________________

(Again we are only interested in the total additional wages/salaries paid by the company to administer the intervention(s). Kindly specify the time period with the $ amount so that we can compute annual estimates).

(Please include only the wages/salaries of personnel that were involved in training, specialist management, surveillance, and monitoring, etc.)

19. What was the size of the workforce before the intervention? ____ employees during _____ (specify year or years)

20. What was the size of the workforce after the intervention? ____ employees during _____ (specify year or years)

21. Do you have any other comments? Are there any company costs associated with low back pain that we have missed?
   If you are aware of the medical-care costs of the injured workers – please state the average medical care costs per injured worker.

If you have any questions please contact:
Supriya Lahiri, Professor, Department of Economics, University of Massachusetts Lowell at 978-934-2789 or email at supriya_Lahiri@uml.edu