OPEN

Cost-Effectiveness and Return-on-Investment of a Participatory Ergonomics Intervention Among Childcare Workers

An Economic Evaluation in a Randomized Controlled Trial

Nidhi Gupta, PhD, Johanna M. van Dongen, PhD, Andreas Holtermann, PhD, Allard J. van der Beek, PhD, Matthew Leigh Stevens, PhD, and Charlotte Diana Nørregaard Rasmussen, PhD

Objectives: To evaluate the cost-effectiveness and return-on-investment (ROI) of 20-week ergonomic intervention to reduce physical exertion at work compared with usual-practice among childcare workers. **Methods:** One hundred ninety workers from 16 institutions were cluster-(institute)-randomized to intervention (n = 96) and usual-practice (n = 94) group. The intervention group participated in three workshops to develop/implement action plans improving ergonomic conditions. The rating of physical exertion (RPE) was measured at baseline and 20-weeks. Employer-perspective-based costs of intervention, absenteeism, and presenteeism were estimated. **Results:** Although statistically non-significant, one-unit reduction in RPE was associated with saving of 592 EUR/worker. Per-EUR invested by the employer was associated with 1.6 EUR (95% CI: –3.1; 6.5) return in the intervention compared with usual practice. **Conclusion:** The intervention tended to gain monetary benefit for the employer. The results should be replicated in larger populations for improved precision of economic evaluation estimates.

Trial registration: ISRCTN10928313

Keywords: childcare, economic evaluation, pain, perceived exertion

Before allocating resources to a workplace intervention, employers not only want evidence on its effectiveness, but also if it is worth their money.[1] Economic evaluations provide such information by relating the difference in effects between two or more interventions to the difference in costs.[2] Thus, economic evaluations of workplace interventions are requested by employers and the society.

Childcare workers generally have several health issues, including musculoskeletal pain, high sickness absence, and a high turnover rate—putting a huge burden on employers and society.[3–5] A recent study based on accelerometer and observational methods among childcare workers has indicated that excessive ergonomic demands, such as forward bending of the back and knee straining postures, could impose risks for musculoskeletal pain and sickness absence.[6] Thus, effective workplace interventions are needed to improve ergonomic conditions among childcare workers.

Participatory ergonomics is an approach aimed at the implementation of interventions to reduce workplace ergonomic risks for prevention of health problems, such as musculoskeletal pain.7 A systematic review on 23 previous studies concluded that participatory ergonomic interventions are moderately effective to reduce health problems among workers, such as manufacturing workers,[8] health care workers,[9] and office workers.[10] A review has indicated, however, that not many studies have explored the economic value of participatory ergonomic interventions.[11] Economic evaluations of participatory ergonomic workplace interventions have been conducted among workers from textile and steel manufacturing,[8,12] healthcare,[8] and transport sector.8 However, we are not aware of studies investigating the economic value of participatory ergonomic workplace interventions among childcare workers.

We recently performed a 20-week participatory ergonomic intervention aiming to reduce physical exertion and musculoskeletal pain among childcare workers in Denmark. The intervention was both feasible and effective in reducing musculoskeletal pain-related sickness absence, but not in improving physical exertion at work and musculoskeletal pain compared with usual practice. However, before the intervention can be taken up by childcare institutions, knowledge of potential economic benefits of the intervention is crucial for employers.

The present study aimed to evaluate the cost-effectiveness and return-on-investment of this intervention compared with usual practice from the employer's perspective.[13]

METHODS

Study Population and Design

This economic evaluation was conducted alongside a cluster-randomized controlled trial (cluster-RCT) with a waiting-list control design. The trial was conducted between August 2017 and July 2018. The trial, as well as the economic evaluation, had a follow-up of 20 weeks. The National Committee on Biomedical Research Ethics, Denmark, reviewed the study and concluded no requirement to obtain a formal approval from the local ethics committee (reference number 16048606). We obtained written, informed consent from all participants before they were enrolled in the trial.

Patients Involvement

This was a workplace intervention, not involving patients. However, workers were not involved in developing the research

From the Department of Musculoskeletal Disorders and PhysicalWork Demands, The National Research Centre for the Working Environment, Copenhagen, Denmark (Dr Gupta, Dr Holtermann, Dr Stevens, Dr Rasmussen); Department of Health Sciences, Faculty of Science, Vrije Universiteit Amsterdam, Amsterdam Public Health Research Institute (Dr van Dongen); Department of Public and Occupational Health, Amsterdam University Medical Center, Vrije Universiteit Amsterdam, Amsterdam Public Health Research Institute, Amsterdam, The Netherlands (Dr van der Beek).

Funding: This study was financially supported by the work environment research fund, Denmark, (grant no. 2-2016-03 20165101186).

Conflict of interest: All authors declare no conflicts of interest.

Author contribution: A.H. and C.N.R. acquired funding for the study. The study was conceptualized by A.H. and C.N.R. C.N.R. was responsible for running the intervention and collecting the data at theworkplaces.N.G. and J.M.D. performed the analyses. N.G. and C.N.R. were responsible for writing the first draft of the manuscript.All authors reviewed, edited, and finalized themanuscript. All authors have read and agreed to the published version of the manuscript.

Clinical significance: Employers generally like to know if participatory ergonomic interventions are worth their money. We found that a participatory ergonomic intervention tended to be cost-effective and has the potential to gain monetary benefits in the childcare sector.

Supplemental digital contents are available for this article. Direct URL citation appears in the printed text and is provided in the HTML and PDF versions of this article on the journal's Web site (www.joem.org).

Address correspondence to: Nidhi Gupta, PhD, National Research Centre for the Working Environment, Lerso Parkalle 105, Copenhagen, DK-2100, Denmark (ngu@nfa.dk).

DOI: 10.1097/JOM.0000000000002510

question and outcome measures or design of the study but they were involved in developing and implementing the intervention.

Workers were not involved in assessing the burden of the intervention—however, the intervention had a minimal burden for the workers, since it was conducted as part of their work (ie, organizational workplace intervention).

A reference group consisting of relevant stakeholders (eg, union members, and internal work environment consultants and ergonomists) were connected to the study since start and gave input to the dissemination plan for the study as well as received information about the results of the study.

Participants

Childcare institutions were recruited with the assistance from the work environment consultants from the municipality of Copenhagen. The eligibility criteria for institutions were to take care of children of 0 to 3 years of age and to employ at least nine workers.

Twenty-nine eligible institutes were recruited. Based on the assumption of obtaining 80% statistical power, an alpha of 0.05, an average cluster size of 12, and intra-class correlation of 0.005, we required approximately 192 participants to statistically demonstrate a reduction of 1 unit in physical exertion at work.[14]

Randomization and Blinding

The randomization was performed at the cluster level with each childcare institution as a cluster. To ensure clusters were balanced regarding the size of the institutions, we split the randomization into two strata based upon the number of workers at each institute. These were small institutes with nine and 12 workers, and large institutes with more than 12 workers. Per stratum, the institutions were randomly assigned to either the intervention or control group in a 1:1 ratio. To maintain allocation concealment, randomization was performed by an independent data manager using a computer-generated randomization scheme. Blinding of the participants was not possible due to the nature of this workplace trial. However, the data collection and data analyses team were blinded.

Intervention

A detailed description of the rationale, development and content of the intervention can be found elsewhere.[14] In brief, the participatory ergonomic intervention consisted of three workshops. The first workshop lasted 3 hours and was conducted in week 2. The two follow-up workshops lasted 1.5 hours each and occurred in weeks 8 and 12 (approximately). In addition, each workplace was offered one visit by an ergonomic consultant. The participatory ergonomics followed six steps: (1) identification of risk factors, (2) analysis of risk factors, (3) solution building, (4) prototype implementation, (5) prototype evaluation, and (6) solution adoption. Intervention implementation was integrated within the existing work tasks. Those in the control group followed usual ergonomic practice from baseline to 20-week follow-up.

Data Collection

Effect Measure

The primary effect measure was self-reported physical exertion at work. This was measured using a single item “How physically demanding do you usually perceive your current job?” with a Likert response scale of 0 to 10, where 0 was “not demanding at all” and 10 was “most demanding.”[15] The information on physical exertion was collected at baseline and 20 weeks follow-up by use of electronic questionnaires sent via text message to the participants’ mobile phone.

Cost Measures

All costs were converted to 2018 Euros using exchange rates from the European Central Bank. As the follow-up period of the intervention was less than 1 year, discounting of the costs and effects was not required.

Cost measures consisted of the cost related to the intervention activities (intervention cost) and those related to health-related productivity loss:

Intervention Cost

Table 1 gives the overview for the elements of the intervention, corresponding resources used, and their unit prices and cost per worker for determining intervention cost.

Staff time: Participation of workers and supervisors in intervention activities (ie, kick-off meeting and workshops) was assessed based on registration of attendance. The time spent on the intervention was subsequently valued based on their expected average monthly gross salaries obtained from the trade union representing childcare workers in Denmark(www.foa.dk/~/media/faelles/pdf/loenmagasiner/2017/infoaloenmagasin6kommunalpr%2011017141815092017%20pdf.pdf).

Ergonomist time: Hours spent on delivery of the workshops and workplace observations was retrieved from the ergonomists delivering these activities. These hours were then valued by using the actual hourly fee charged during the project by the ergonomists (which also covers the preparation for the intervention activities and their travel time).

Consumables: Information on the cost of materials (printouts and posters) as well as fruit/snack/coffee consumed in various intervention activities was collected via invoices.

Overhead: An overhead cost (such as cost of booking the meeting rooms, telephone bills, electronics usage, etc) of 20% of the intervention cost was added to the total intervention cost.

Health-Related Productivity Loss Cost

Via text message, information on two indicators of health-related productivity loss—absenteeism (days missed from work due to sickness absence) and presenteeism (productive days lost due reduced performance, related to health problems, while being present at work)—were measured every 4 weeks during the follow-up using a questionnaire.[16] The questions were;

(a) Over the past 4 weeks, have you experienced any health-related problems while at work?
(b) During the past 4 weeks, how much did your health problems affect your performance while you were working? 0 to 10, where 0 = health problems had no effect on my work, and 10 = health problems completely prevented me from working.
(c) How many workdays in total within the last 4 weeks have you been absent from work due to pain in the body?

We performed the following calculations to estimate health-related productivity loss (in days) at each time point (baseline, 4, 8, 12, 16, and 20 weeks) of data collection;

1. subtracted sickness absence days from assumed 20 working days in last 4 weeks to calculate “productive days at work.”
2. multiplied productive days at work with responses on degree of health problems affecting work performance (question b; response [scale: 0–10]/10) to estimate productive days lost due to presenteeism among those who reported experiencing any health-related problems while being a work. Workers who reported no health-related problems while at work were estimated to have zero lost productive days at work.
3. summed productive days lost due to presenteeism and sickness absence at 4, 8, 12, 16, and 20 weeks.

We used the Human-Capital Approach to value both absenteeism and presenteeism of health-related productivity loss. This approach assumes that a sick worker will not be replaced by another worker, nor will her/his tasks be compensated for by others during

TABLE 1. Cost Associated With Each Intervention Activity in the Intervention Group ($n = 96$)

Intervention Activity	Participants	N	Total Time Invested Hours	Unit Prices EUR/hr	Total Costs EUR	Cost/Worker EUR
Kickoff meetings						
	Supervisors	8	18	25	442	5
Workshop 1						
	Qualified childcare workers	48	144	23	3379	35
	Non-qualified childcare workers (assistants)	32	96	22	2114	22
	Non-qualified childcare workers (helpers)	0	0	20	0	0
	Supervisors	4	12	25	295	3
	Ergonomist	8	24	94	2256	24
Workshop 2						
	Qualified childcare workers	43	64.5	23	1513	16
	Non-qualified childcare workers (assistants)	23	34.5	22	760	8
	Non-qualified childcare workers (helpers)	1	1.5	20	30	0
	Supervisors	5	7.5	25	184	2
	Ergonomist	8	12	94	1128	12
Workshop 3						
	Qualified childcare workers	40	60	23	1408	15
	Non-qualified childcare workers (assistants)	18	27	22	595	6
	Non-qualified childcare workers (helpers)	1	1.5	20	30	0
	Supervisors	8	12	25	295	3
	Ergonomist	8	12	94	1128	12
Observations at workplaces	Ergonomist	8	3	94	313	3
Consumables	Posters printing				235	2
	Printouts of accompanied materials				12	0
	Snacks and fruits consumption				349	4
20% overhead cost					3293	34
Total intervention cost/worker (EUR)						206

"Non-qualified" meant that these workers did not have formal qualification/certification to be the childcare workers.

the complete duration of absence. Thus, the entire period of health-related productivity loss was valued using gross monthly salary estimates of the participants using the procedure explained above.

Statistical Analyses

All analyses were performed according to the intention to treat principle and results of the analyses were considered statistically significant at $P < 0.05$ level. Data were analyzed using Stata (version 12, Stata Corp, College station, TX).

Approximately 24%of the values in the costs and effects were missing. The missing values were imputed using multivariate imputation by chained equations (MICE) with predictive mean matching.[17] In total, 10 complete sets of data were created to reduce the loss of efficiency less than 5% (ie, the efficiency loss compared with having an infinite number of imputed data sets). The economic evaluation analyses were then performed on all 10 datasets. Thereafter, the estimates from all datasets were pooled using Rubin rules.[18]

Two economic evaluations—cost-effectiveness and return on investment (ROI)—were performed; both from an employer's perspective:

Cost-Effectiveness

To determine the mean incremental difference in cost and effect on physical exertion at work between the intervention and control groups, we used seemingly unrelated regression (SUR). The SUR runs two regressions to determine incremental cost and incremental difference simultaneously, adjusting for any potential correlation between costs and effects.[19] The regression for determining incremental cost difference was adjusted for baseline cost (cost-related to health-related productivity loss), while the regression for determining incremental effect difference was adjusted for baseline physical exertion at work. We also used bias-corrected and accelerated bootstrap intervals with 5000 replications to determine the uncertainty surrounding the mean differences in costs. Thereafter, the incremental cost and effect ratios (ICER) were calculated by dividing the corrected cost difference by the corrected effect difference. Subsequently, we plotted the 5000 bootstrapped cost-effect pairs on a cost-effectiveness plane, graphically showing the uncertainty around the ICER (Fig. 1). Additionally, cost-effectiveness acceptability curves were plotted to determine the probability of the intervention being more cost-effective compared with usual practice as a function of the employer's willingness to pay per unit decrease in physical exertion at work (Results shown in Appendix A, http://links.lww.com/JOM/B73).

Return on Investment (ROI)

For the ROI analysis, costs were defined as the mean difference in intervention costs (Table 1) between intervention and control group (ie, a fixed cost of 206 EUR as shown in Table 1).

Benefits were defined as the mean difference (determined using ordinary least squares linear regression) in the health-related productivity loss costs (presenteeism and sickness absence) between intervention and control group. Positive benefits indicate a cost saving while negative benefits indicate a monetary loss.

Three main indicators of ROI were determined:

$$net\ benefit = benefit\text{–}costs \quad (1)$$

$$benefit{-}cost\ ratio = benefits/costs \quad (2)$$

$$ROI = \left(\frac{benefits{-}costs}{costs}\right) * 100 \quad (3)$$

Net benefit more than 0, benefit–cost ratio more than 1, and ROI more than 0% indicate a positive financial returns for the employer from the intervention. Bootstrapped 95% confidence interval

(CI) around these three indicators of ROI was determined using 5000 replications. The probability of financial returns was determined based on the proportion of 5000 estimates of the three indicators indicating cost savings.

To assess the robustness of the results from main analysis, a sensitivity analysis was performed on complete cases only.

RESULTS

Flow of the Participants

Of the 222 eligible participants, 190 agreed to participate, took part in baseline measurements, and were randomized to the intervention (n = 96) and control (n = 94) groups. After the 20-week intervention, 19 (20%) in the intervention group and 16 (17%) in the control group were lost to follow-up. This was because they stopped working at the childcare institute.[13] A detailed flow chart is shown in our previous published study.[13]

Baseline Descriptives

Table 2 shows the baseline descriptive of the 190 workers randomized to the intervention and control groups. Both groups were similar with respect to all descriptive variables except a slight difference for their gender distribution. Additionally, there were differences in baseline physical exertion (0 to 10) and health-related productivity loss (in DKK).

Intervention Costs

Costs of intervention activities are shown in Table 1. On average, the intervention cost was 206 EUR per worker.

Cost-Effectiveness

Cost and Effect Differences

Table 3 presents the estimated incremental cost and effect differences between groups. A small, statistically non-significant difference was found for physical exertion between the intervention and control group. In the intervention group, on average, physical exertion decreased by 0.24 (95% CI –0.93 to 0.45) from baseline to follow-up compared with the control group. The mean incremental total cost (including cost of intervention, presenteeism, and sickness absence) was 143 EUR per worker (95% CI –1050 to 778) lower in the intervention group compared with control group, but this was also not statistically significant.

Cost-Effectiveness

We found an ICER of 592 EUR. This indicates that 592 EUR would, on average, be saved in the intervention group compared with the control group per 1 unit reduction in physical exertion. Figure 1 and Table 3 show that most incremental cost-effectiveness (CE) pairs were located on the southeast quadrant of the CE plane, indicating that the intervention was on average less costly and more effective compared with usual practice for reducing physical exertion. Thus, on average, the intervention was found to dominate usual practice for reducing physical exertion.

With employer's willingness to pay 0 EUR per unit reduction in physical exertion, the probability of the intervention being cost-effective compared with control group was about 60%. This probability increased with increasing values of willingness to pay and reached its maximum of 80%, at a willingness to pay threshold of about 2000 EUR per worker (Appendix A visualizing results on willingness to pay, http://links.lww.com/JOM/B73).

Return-on-Investment (ROI)

The results of ROI were not statistically significant. However, the total benefit was 336 EUR (95% CI –606 to 1374) in the intervention group compared with control group. The mean net benefit (subtracting intervention cost from total benefit) was 130 EUR (95% CI –850 to 1134) per worker. The cost–benefit ratio was 1.63 (95% CI –3.1 to 6.5), suggesting that each EUR invested in the intervention compared with usual practice resulted in cost savings of 1.63 EUR per worker. The ROI was 63% (95% CI –412% to 551%), indicating a return of 63% of investment per worker in the intervention compared with control group. The estimated maximal probability of return was 0.67, indicating 67% probability for the employer to expect a positive return on investment from the intervention.

TABLE 2. Baseline Descriptive of the 190 Workers Involved in the Analyses

	Intervention (n = 96)			Control (n = 94)		
Descriptive	*N*	M(SD)	%	*N*	M(SD)	%
Age, y	96	37 (12)		94	38 (12)	
BMI, kg/m^2	96	25.7 (5.2)		87	25.0 (5.9)	
Gender (women)	78		81	88		94
Type of workers						
Childcare teachers	56		58	59		63
Assistants	34		35	29		31
Others	6		6	6		6
Ethnicity (born in DK)	87		91	77		82
Smoking (smokers)	26		27	19		20
Physical exertion (0 – 10)	96	5.6 (1.8)		94	6.2 (1.6)	
Presenteeism						
Days (0 – 100)*	96	3.5 (0.46)		94	4.7 (0.49)	
Cost (EUR)	96	576 (77)		94	774 (80)	
Sickness absence						
Days (0 – 100)*	96	0.42 (0.23)		94	0.66 (0.42)	
Cost (EUR)	96	63 (34)		94	111 (57)	
Health-related productivity loss						
Days (0 – 100)*	96	3.9 (0.50)		94	5.4 (0.58)	
Cost (EUR)	96	639 (83)		94	885 (96)	

Information on some of the characteristics (age, gender, smoke, BMI, and ethnicity) of the workers has been published previously (13); presented information on presenteeism, sickness absence, and health-related productivity loss was obtained from the imputation models.

*Based on the assumption of 20 working days in a month.

TABLE 3. Results from the Main Analysis and Sensitivity Analysis on Differences Between Intervention and Usual Practice Group in Pooled Mean Costs and Physical Exertion, ICERs, and the Distribution of Incremental Cost-Effectiveness Pairs Around the Quadrants of the Cost-Effectiveness Planes from Employer's Perspective

	Sample Size		Net Costs (95% CI)	△PE (95% CI)	ICER	Distribution in Cost-Effectiveness Plane (%)			
Analysis	Intervention	Control	EUR	Points	EUR/point	NE*	SE†	SW‡	NW§
Main analysis—imputed dataset	96	94	– 143 (– 1050 – 778)	– 0.24 (– 0.93 – 0.45)	592	0.28	0.49	0.14	0.09
SA1—complete-case analysis	41	44	– 175 (– 1554 – 1205)	0.07 (– 0.82 – 0.70)	– 2654	0.26	0.31	0.28	0.15

Note: cost and effect differences were corrected for their baseline values.
CE-plane, cost-effectiveness-plane; ICER, incremental cost-effectiveness ratio; PE, physical exertion.
*Refers to the northeast quadrant, indicating that the intervention is more effective and more costly compared with usual practice.
†Refers to the southeast quadrant, indicating that the intervention is more effective and less costly compared with usual practice.
‡Refers to the southwest quadrant, indicating that the intervention is less effective and less costly compared with usual practice.
§Refers to the northwest quadrant, indicating that the intervention is less effective and more costly compared with usual practice.

Sensitivity Analysis

When re-running the analysis on complete cases only, we observed similar results to those of the main analysis (Tables 3 and 4). The only difference was found in the cost-effectiveness analysis where we observed a slight increase (instead of reduction) in the physical exertion in the intervention compared with usual practice that led to a difference in the ICER value obtained.

DISCUSSION

Overall, we found tendencies for the participatory ergonomics intervention for reducing physical exertion among childcare workers to be cost-effective and cost-beneficial from an employer's perspective, compared with usual practice. We found a statistically non-significant reduction in incremental cost of 143 EUR (95% CI –1050 to 778) and in physical exertion of 0.24 (95% CI –0.93 to 0.45) in the intervention group compared with the control group. By implementing the intervention, employers could save 592 EUR per worker per unit reduction in physical exertion. Accordingly, an employer would gain 1.63 EUR (95% CI –3.1 to 6.5) per EUR invested in the intervention compared to usual practice.

We found that employers can save about 592 EUR per unit reduction in physical exertion. Until now, not many studies using participatory ergonomic interventions to reduce health risk among workers have performed an economic evaluation.[8,12,20] Additionally, to the best of our knowledge, we could not find any study that aimed to reduce physical exertion among workers using participatory ergonomics. Thus, we compared our results with participatory ergonomic studies targeting other outcomes, such as disability duration, musculoskeletal pain, and sick leave. One study conducted a 12-month participatory ergonomic programme aiming to reduce low back pain among workers from transport, manufacturing, and healthcare sector.[8,21] This study did not perform a cost-effectiveness analysis from company perspective, but from societal perspective and observed the intervention to not be cost-effective (ICER of 23,749 EUR/unit of low back pain). Our results are in line with another study evaluating the cost-effectiveness of a participatory ergonomic intervention to reduce musculoskeletal pain-related

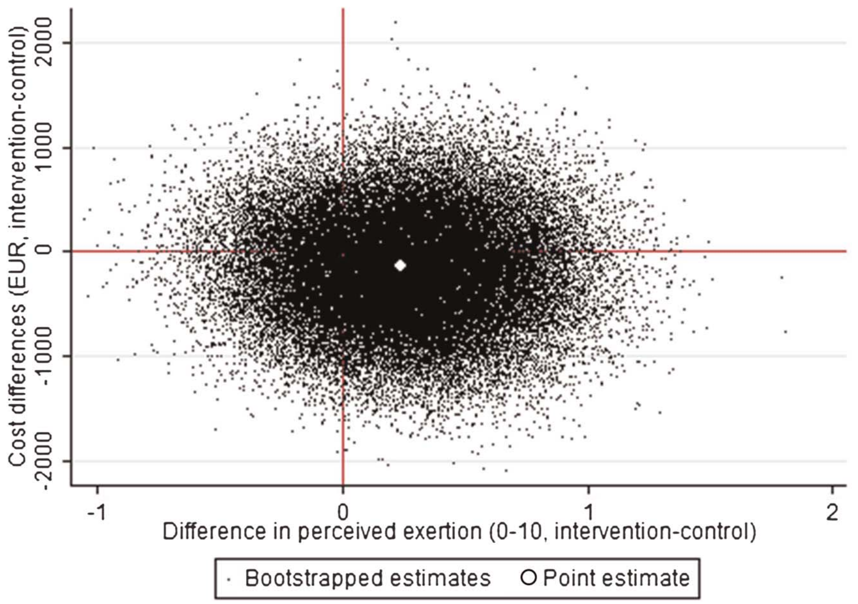

FIGURE 1. Cost-effectiveness plane indicating the uncertainty around incremental cost-effectiveness ratio for reducing physical exertion at work in intervention control compared with usual practice. On x-axis, positive change meant reduction in physical exertion and vice versa.

TABLE 4. Results of the Main Analysis and Sensitivity Analysis Indicating Differences Between Intervention and Control Group in Indicators of Return-On-Investment from Employer's Perspective

	Sample Size		Net Benfit (95% CI)	Cost-Benefit Ratio (95% CI)	ROI
Analysis	Intervention	Control	EUR	Points	EUR/Point
Main analysis—imputed dataset	96	94	130 (– 850 – 1134)	1.6 (– 3.1 – 6.5)	63% (– 412 – 551)
Complete-case analysis	41	44	175 (– 1214 – 1550)	1.9 (– 4.9 – 8.5)	85% (– 589 – 753)

disability duration.[20] This study observed that participatory ergonomics can avert 2106 disability days in 23 months time. Keeping in mind the total intervention cost of 25,402 USD, the participatory ergonomic intervention was found to be cost-effective (cost effectiveness ratio of 12.06 USD/disability day averted). However, this study lacked a control group and thus, it is difficult to interpret if such participatory ergonomic programme was cost-effective compared with usual practice, like in our study.

We found a rather small, statistically non-significant reduction in physical exertion of 0.24 (scale of 0 to 10). This could be the reason behind the uncertainty in the ICER of our study (Fig. 1). These results are in contrast to the few previous ergonomic interventions that have been effective in preventing musculoskeletal pain among workers.[7,9] However, our results are in line with other studies observing limited effectiveness of such interventions.[22,23] A reason behind observing a small, non-significant reduction could be due to implementation failure—only half of the intervention group reported that the intervention led to actual change in their work.[13] Another reason could be the difficulty in evaluating the participatory ergonomic intervention. The actual content (such as risk identification and solution development) of the intervention was a black box for us, a typical challenge in most participatory interventions.[24] Thus, future studies should choose an outcome that might be more sensitive when evaluating participatory ergonomic interventions.

The intervention group had lower incremental cost compared with the control group, although the confidence interval was wide. We found that the total cost was 143 EUR lower in the intervention group even after adding the intervention cost of 206 EUR, compared with the control group. These results indicate that even if the intervention did not lead to large reduction in physical exertion, it led to other (health) benefits leading to reduction in other cost indicators in the intervention group (eg, the intervention group had fewer presenteeism-related working days than the control group in 20-weeks period) (Table 2).

We also found that our intervention had a positive return on investment. Specifically, employers can expect to almost double their investment with a moderate probability of 67%. This is in line with participatory ergonomic interventions for preventing musculoskeletal pain in manufacturing, textile, and electric workers. [12,20,25] Two of these previous studies found benefit–cost ratio of as high as 5.5 (12) and 10.6 (20) compared with our benefit–cost ratio of 1.6. These differences can be explained by the difference in study design. These previous studies did not use a randomized controlled design, but a pre-post design without a control group. Previous studies have shown that economic evaluations for worksite health programs tend to be more favorable for non-randomized trial than randomized trials.[26,27] However, non-randomized study design cannot account for potential changes happening in parallel to the intervention. On the other hand, our study used a gold standard study design, the randomized controlled trial, which is more likely to provide unbiased estimates of intervention's cost-effectiveness.

Overall, our results related to cost-effectiveness and return on investment had rather wide confidence intervals. The reasons behind this uncertainty of the estimates related to economic evaluations could be the skewed cost data. An additional reason could be the limited sample size. In this study, the sample size was calculated for the effectiveness study and not specifically for an economic evaluation, which generally require larger sample sizes.28 It might also be, however, that the total cost difference will be more favorable with a longer follow-up duration. A longer follow-up duration generally leads to limited intervention cost and higher saving due to improved productivity that might in turn result in higher probabilities of the intervention being cost-effective and cost-saving. Thus, future studies on participatory ergonomic interventions to reduce physical exertion and prevent musculoskeletal pain among childcare workers should be conducted using large sample size and longer follow up.[29]

Implication of the Results

We found that although our results were non-significant, the intervention tended to be cost-effective and has potential, with moderate probability, for employers to approximately double their investment. However, due to wide confidence intervals of these economic evaluation estimates, the intervention ought to be repeated in a larger study sample and longer follow-up duration to retrieve more confident estimates of the economic evaluations. Second, future studies should develop and evaluate interventions designed to minimize intervention cost and maximize effectiveness. For example, ways to reduce intervention cost could be by reducing the duration of the workshops, reducing the number of workshops and incorporate technology to reduce the administrative and user burden.

Strengths and Limitations

An important strength of the present study is its pragmatic cluster RCT design, which enabled us to study the (cost-)effectiveness and cost-benefit of participatory ergonomics in real life. Another strength is the usage of text messages sent every 4 weeks to collect information on cost and effect that minimize recall bias and capture potential fluctuations in the data. Another strength is the use of non-parametric bootstrapping methods to determine the uncertainty around our estimates, which are recommended to handle highly skewed cost data.

One limitation was the 25% missing values in our data due to non-response and drop-out/lost-to-follow-up. We imputed missing values using multivariate imputation methods, which is recommended practice for dealing with missing values in economic evaluation research.[30] Results of the complete-case analysis, where no imputation was applied, were found to be rather similar to results obtained from main analysis. Thus, the degree of dropping out of participants during the followup time did not influence the main results. Another limitation is that we used self-reported data on sickness absence and presenteeism which may add bias, especially when workers were not blinded to the allocation of the intervention. However, we used widely-used self-reported measures for presenteeism and absenteeism with a recall period of 4 weeks that might have limited the risk of recall bias.16 Additionally, we assessed sickness absence and presenteeism every 4 weeks to assure that recall bias was small. It is questionable whether the costs of the prioritized ergonomic solutions based on workshops have to be considered as intervention costs. Most solutions were associated with no costs, and if there were any costs associated, it was miniscule. Logically, adding up of these costs would have not have led to a significantly larger cost difference between the two groups. An additional limitation of the study is the lack of power calculation specific to economic evaluation, which usually requires larger sample sizes than the sample sizes required for effectiveness analysis.[28]

CONCLUSION

We found indications that a participatory ergonomic intervention designed to reduce exertion and musculoskeletal pain among childcare workers is likely to be cost-effective from the employer's perspective. Employers, with moderate probability, can expect to almost double their investment by implementing the intervention compared with usual practice. The intervention should be performed in a larger sample size to retrieve more confident estimates of the economic evaluations.

ACKNOWLEDGMENTS

The authors would like to thank the whole team involved in the intervention at the National Research Centre for The Working Environment, the involved consultants from the Work Environment Consultancy of Copenhagen, and all participants in the study.

REFERENCES

1. Burdorf A. Economic evaluation in occupational health–its goals, challenges, and opportunities. *Scand J Work Environ Health*. 2007;33:161–164.
2. van Dongen JM, van Wier MF, Tompa E, et al. Trial-based economic evaluations in occupational health: principles, methods, and recommendations. *J Occup Environ Med*. 2014;56:563–572.
3. Linnan L, Arandia G, Bateman LA, Vaughn A, Smith N, Ward D. The health and working conditions of women employed in child care. *Int J Environ Res Public Health*. 2017;14:283.
4. Shimaoka M, Hiruta S, Ono Y, Nonaka H, Hjelm EW, Hagberg M. A comparative study of physical work load in Japanese and Swedish nursery school teachers. *Eur J Appl Physiol Occup Physiol*. 1998;77:10–18.
5. OECD. Encouraging Quality in Early Childhood Education and Care (ECEC).
6. Holtermann A, Fjeldstad Hendriksen P, Greby Schmidt K, Jagd Svendsen M, Nørregaard Rasmussen CD. Physical work demands of childcare workers in denmark: device-based measurements and workplace observations among 199 childcare workers from 16 day nurseries. *Ann Work Expo Health*. 2020;64: 586–595.
7. Rivilis I, Van Eerd D, Cullen K, et al. Effectiveness of participatory ergonomic interventions on health outcomes: a systematic review. *Appl Ergon*. 2008;39: 342–358.
8. Driessen M, Proper K, Anema J, Knol D, Bongers P, van der Beek A. The effectiveness of participatory ergonomics to prevent low back pain and neck pain: results of a cluster randomised controlled trial. *Occup Environ Med*. 2011;68:A63.
9. Rasmussen CDN, Holtermann A, Bay H, Søgaard K, Birk Jørgensen M. A multifaceted workplace intervention for low back pain in nurses' aides: a pragmatic stepped wedge cluster randomised controlled trial. *Pain*. 2015;156: 1786–1794.
10. Bohr PC. Efficacy of Office ergonomics education. *J Occup Rehabil*. 2000;10: 243–255.
11. Sultan-Taïeb H, Parent-Lamarche A, Gaillard A, et al. Economic evaluations of ergonomic interventions preventing work-related musculoskeletal disorders: a systematic review of organizational-level interventions. *BMC Public Health*. 2017;17:935.
12. Tompa E, Dolinschi R, Natale J. Economic evaluation of a participatory ergonomics intervention in a textile plant. *Appl Ergon*. 2013;44:480–487.
13. Rasmussen CDN, Sørensen OH, van der Beek AJ, Holtermann A. The effect of training for a participatory ergonomic intervention on physical exertion and musculoskeletal pain among childcare workers (the TOY project) - a wait-list cluster-randomized controlled trial. *Scand J Work Environ Health*. 2020;46: 429–436.
14. Rasmussen CDN, Hendriksen PR, Svendsen MJ, et al. Improving work for the body - a participatory ergonomic intervention aiming at reducing physical exertion and musculoskeletal pain among childcare workers (the TOY-project): study protocol for a wait-list cluster-randomized controlled trial. *Trials*. 2018; 19:411.
15. Borg G. *Physical Performance and Perceived Exertion*. Sweden: C.W.K. Gleerup; 1962.
16. Aboagye E, Jensen I, Bergström G, Hagberg J, Axén I, Lohela-Karlsson M. Validity and test-retest reliability of an at-work production loss instrument. *Occup Med (Lond)*. 2016;66:377–382.
17. Zhang Z. Multiple imputation with multivariate imputation by chained equation (MICE) package. *Ann Transl Med*. 2016;4:30.
18. Brand J, van Buuren S, le Cessie S, van den Hout W. Combining multiple imputation and bootstrap in the analysis of cost-effectiveness trial data. *Stat Med*. 2019;38:210–220.
19. Willan AR, Briggs AH, Hoch JS. Regression methods for covariate adjustment and subgroup analysis for non-censored cost-effectiveness data. *Health Econ*. 2004;13:461–475.
20. Tompa E, Dolinschi R, Laing A. An economic evaluation of a participatory ergonomics process in an auto parts manufacturer. *J Safety Res*. 2009;40:41–47.
21. Driessen M, Bosmans J, Proper K, Anema J, Bongers P, van der Beek A. The economic evaluation of a participatory ergonomics programme to prevent low back and neck pain. *Work*. 2012;41 suppl 1:2315–2320.
22. Haukka E, Leino-Arjas P, Viikari-Juntura E, et al. A randomised controlled trial on whether a participatory ergonomics intervention could prevent musculoskeletal disorders. *Occup Environ Med*. 2008;65:849–856.
23. Morken T, Moen B, Riise T, et al. Effects of a training program to improve musculoskeletal health among industrial workers—effects of supervisors role in the intervention. *Int J Ind Ergon*. 2002;30:115–127.
24. Rasmussen CDN, Lindberg NK, Ravn MH, Jørgensen MB, Søgaard K, Holtermann A. Processes, barriers and facilitators to implementation of a participatory ergonomics program among eldercare workers. *Appl Ergon*. 2017;58:491–499.
25. de Jong AM, Vink P. Participatory ergonomics applied in installation work. *Appl Ergon*. 2002;33:439–448.
26. van Dongen JM, Proper KI, van Wier MF, et al. Systematic review on the financial return of worksite health promotion programmes aimed at improving nutrition and/or increasing physical activity. *Obes Rev*. 2011;12:1031–1049.
27. Baxter S, Sanderson K, Venn AJ, Blizzard CL, Palmer AJ. The relationship between return on investment and quality of study methodology in workplace health promotion programs. *Am J Health Promot*. 2014;28:347–363.
28. Knox S. Sample size calculation in economic evaluation. In: (CREST) CREST, ed. 2012. Available at: https://www.uts.edu.au/sites/default/files/2019-04/crest-factsheet-sample-size-in-economic-evaluation.pdf. Accessed June 2019.
29. Claxton K. The irrelevance of inference: a decision-making approach to the stochastic evaluation of health care technologies. *J Health Econ*. 1999;18: 341–364.
30. Blough DK, Ramsey S, Sullivan SD, Yusen R. The impact of using different imputationmethods for missing quality of life scores on the estimation of the costeffectiveness of lung-volume-reduction surgery. *Health Econ*. 2009;18:91–101.

