



Research article

Risks, solutions and implementation of a participatory ergonomic intervention in 16 day nurseries: A process evaluation of the TOY wait-list cluster-randomized controlled trial

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ARTICLE INFO

Keywords:

Childcare workers
Musculoskeletal
Occupational health
Sickness absence

ABSTRACT

More evidence-based initiatives to reduce physical work demands during childcare work to prevent ill health and promote the ability to care for the children among childcare workers are needed. In a process evaluation performed alongside a two-arm, cluster-randomized study with a waiting-list control among 16 day nurseries lasting 20-weeks that significantly reduced musculoskeletal pain-related sickness absence we investigated 1) risk factors and solutions perceived by the childcare workers, and 2) implementation of the intervention. Most of the perceived risk factors were categorized as physical (70 %) with most of the suggested solutions also being categorized as physical (61 %). The remaining risk factors were categorized as organizational risk factors (16 %) and psychosocial risk factors (13 %). The remaining solutions were distributed almost equally between the organizational (20 %) and psychosocial categories (19 %). About half (51 %) of the action plans showed high implementation success. Of 16 workshops, 100 % were delivered with a fidelity of 83 %. Average participation, exposure, responsiveness and implementation were 68 %, 56 %, 83 % and 47 %. The implementation score differed for timing of intervention but not for nursery characteristics. This study showed that complex and diverse participatory ergonomic interventions should focus on physical, organizational and psychosocial factors to have a positive effect.

1. Introduction

Childcare workers are subject to many work-related risk factors [1]. Childcare workers in Denmark frequently indicate experiencing a substantial physical workload and perceived physical exertion while at work, coupled with a notable prevalence of musculoskeletal pain and elevated rates of sickness absence [2]. Using movement sensors, we found high exposures to forward bending of the trunk and knee straining postures among Danish childcare workers [3]. Thus, we consider it important to develop and evaluate initiatives to reduce physical work demands during childcare work to prevent ill health and promote the ability to care for the children among childcare workers.

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<https://doi.org/10.1016/j.heliyon.2024.e24167>

Received 3 November 2023; Received in revised form 3 January 2024; Accepted 4 January 2024

Available online 5 January 2024

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Participatory ergonomics are commonly used as an organizational-level workplace intervention to prevent musculoskeletal pain [4, 5]. Participatory ergonomics is based on the involvement of the workers, taking differences in work tasks, work flows and individual preferences and abilities between workers into account [6]. Worker involvement fosters responsibility and ownership in the processes of identifying risks, developing solutions, and formulating an operational implementation plan [7]. Previous participatory ergonomics interventions have been conducted in many job groups, e.g. manufacturing workers [8], construction [9], health care workers [10] and kitchen workers [11]. To our knowledge, the participatory ergonomics approach to reduce physical exertion and musculoskeletal pain has not previously been investigated in larger interventions among childcare workers.

The available evidence regarding the efficacy of participatory ergonomics to reduce physical exertion, musculoskeletal pain, and musculoskeletal-related sickness absence is inconclusive [5,11–13]. While there is knowledge about factors associated with musculoskeletal pain, interventions in physical ergonomics—such as reducing physical workload through the use of lifting aids—and organizational ergonomics—such as job rotations [13,14]—have not demonstrated success in preventing musculoskeletal pain. Notably, psychosocial factors emerge as significant risk factors to musculoskeletal pain, suggesting that a comprehensive participatory ergonomics intervention, encompassing a psychosocial component, may prove effective for reducing musculoskeletal pain [15,16].

We conducted a 20-week randomized waiting-list controlled participatory ergonomics intervention among 190 childcare workers from 16 day nurseries aiming at reducing perceived physical exertion and musculoskeletal pain and musculoskeletal pain-related sickness absence. The evaluation of the effectiveness of the intervention showed that the 20-week participatory ergonomics intervention in childcare workers significantly reduced musculoskeletal pain-related sickness absence, but not the primary outcomes physical exertion and musculoskeletal pain [17].

A participatory approach may result in many different types of problem solving, because they are defined by the workers themselves [5,6]. It is therefore important to open the “black box” and elicit the implementation processes, not only to gain additional insight into what went on, but also to assess why the interventions were or were not effective. Furthermore, it will provide important knowledge for future implementation of participatory ergonomics in childcare workers.

Workplace interventions at the organizational level are complex social interventions, involving multiple interacting components at both individual and workplace levels, exerting unpredictable influences on intervention delivery and contents [18]. Solely conducting an effect evaluation provides insight into only a fraction of the causal assumptions in the program logic [19,20], and such an evaluation risks dismissing the program theory hypothesis due to implementation failure (type III error). Thus, both the effects and the implementation of an intervention need to be evaluated.

Implementation encompasses two overarching aspects: 1. Delivery of the intervention which includes the dose, content, and quality of the intervention; and 2. Receiving the intervention, referring to the intended amount received and how participants perceive it [21, 22]. The overall context of the intervention, e.g. the time and place where an intervention is implemented also influence the intervention process and outcomes [23]. Furthermore, the selection of research designs, such as waiting-list designs (e.g., stepped-wedge design), where the intervention is implemented to randomized groups in phases, has the potential to alter the intervention’s implementation over time (e.g., with increased experience among intervention deliverers) [24,25]. Thus, contextual factors, like workplace characteristics and timing of delivery should also be evaluated in a process evaluation of organizational-level workplace interventions.

Therefore, the aim of this study was twofold: 1) to gain insight into the processes of a participatory ergonomics intervention with emphasis on identified risk factors and solutions and 2) to evaluate the implementation (delivery and receipt) of the participatory ergonomics intervention and to evaluate the importance of context (nursery characteristics and timing of intervention) and the impact on implementation.

2. Methods

The current process evaluation was performed alongside a two-arm, cluster-randomized study with a waiting-list control among childcare workers. The process evaluation used a mixed methods design with both qualitative (action plans and evaluation sheets) and quantitative measures. The intervention investigated whether it is possible to reduce perceived physical exertion and musculoskeletal pain through a participatory ergonomic intervention. Details regarding the recruitment procedures, inclusion criteria and intervention are presented in the protocol paper that includes an outline of the process evaluation [26]. The project was conducted in 16 day nurseries in Copenhagen of which eight nurseries received the intervention first (intervention group), and the eight remaining nurseries received the intervention later and functioned as controls (wait-control group). Measurements were performed at baseline, at 20-weeks and at 40-weeks follow-up. This process evaluation focused on both the intervention group and wait-control group (two intervention rounds).

The study was prospectively registered in the ISRCTN Registry (ISRCTN10928313). The TIDieR checklist for reporting of interventions [27] were used to ensure comprehensive reporting (Additional file).

2.1. Study population

The study population for this process evaluation consisted of 190 participants, of whom 96 were allocated to the intervention group (8 day nurseries) and 94 were allocated to the wait-control group (8 day nurseries). To recruit day nurseries, ergonomic consultants from Work Environment Consultancy Copenhagen (WECC) presented the project at a meeting with the region managers of the day nurseries. Eligibility criteria for participation in the study for the nurseries were: (i) childcare for children aged 0–3 years, (ii) ≥ 9 childcare workers, and (iii) no recent (within the previous year) participation in an ergonomics course from WECC. In total, 29 eligible nurseries wanted to participate, and all their childcare workers were eligible for participation. The study was dimensioned to enroll

approximately 200 childcare workers which corresponded to 16 day nurseries which then were randomized to the study (see more details about randomization in protocol). Since this was an organizational intervention, all childcare workers at the nursery were expected to participate.

2.2. The intervention

The intervention consisted of three participatory ergonomic workshops that were conducted at each day nursery during regular staff meetings. An ergonomic consultant (an occupational therapist or a physiotherapist) from WECC facilitated the workshops. It was presented to the participants that the main idea of the intervention was to integrate participatory ergonomic action plan initiatives into their core work tasks. The participatory ergonomics intervention followed six steps, which was inspired by the participatory ergonomics framework created by Haines and colleagues [7]. The steps are shown in Fig. 1. At the first workshop, pain mapping and risk identification was conducted in plenum by the workers. The definition of risks in the current study were ergonomic risk factors in workplace situations that could cause wear and tear on the body and could potentially cause injury. These could include awkward postures, forceful motion, stationary position, noise, stressful situations and so on. Solution building with use of the *prevention flower* were conducted in working groups across working teams, and suggestion of action plans and implementation were conducted in each childcare working teams [26]. The second workshop started with evaluation of implementation of the suggested solutions, followed by the teams making new action plans. The third workshop included evaluation of the new action plans and a discussion in plenum of how to adopt the changes and continue the implementation (see Fig. 1).

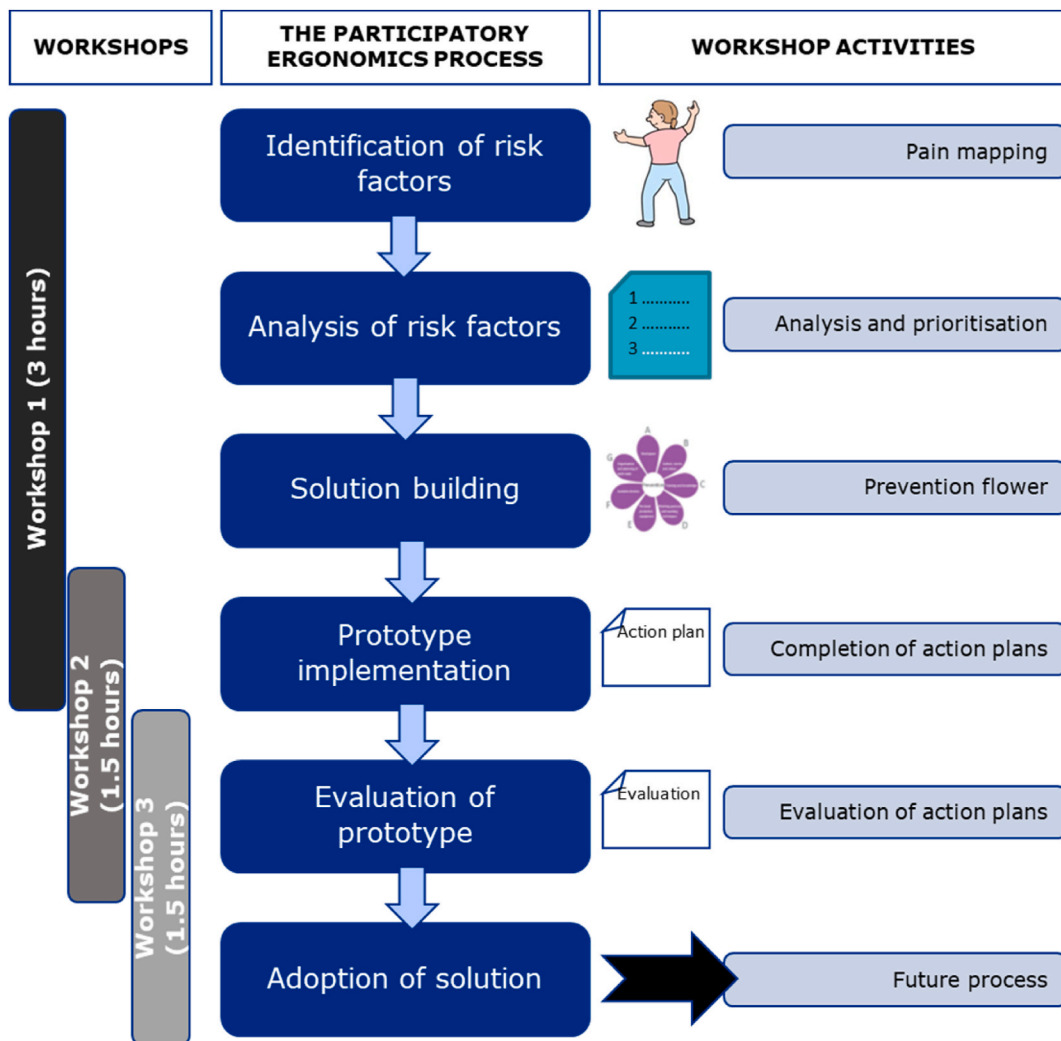


Fig. 1. Steps of the participatory ergonomics process at each workshop and related workshop activity. The steps were inspired by Haines and et al. [7].

2.3. Theory and program logic

Wilson (1995) defined participatory ergonomics as ‘the involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goal’ [28]. Active participation of workers in the process is vital, ensuring that individuals assume responsibility for risk identification, solution development, and the implementation of changes [29]. Despite numerous studies assessing participatory ergonomics intervention processes [5,6,8,29–31], particularly concerning implementation, there is a need for more consistent description of key characteristics to advance the field of ergonomics [5]. Knowledge of the actual content of the interventions, such as risk characteristics and the specific solutions suggested, is limited [29,30]. The process of participatory ergonomics interventions is therefore considered to be a “black box [21]. In most other publications of participatory ergonomics studies, the contents of the interventions were only briefly mentioned. However, some studies have tried to illicit the content of the participatory ergonomics process, and find that risks and solutions can be categorized into three overall themes; physical, organizational, and psychosocial [10,30]. In the study protocol, we provided an a priori program logic [26] that describes the expected pathway from the intervention to the reduction in physical exertion. We expected the employees to be able to identify risks related to physical exertion and musculoskeletal pain. They were envisioned to implement solutions with an intermediate impact, targeting the reduction of both physical and psychosocial work demands (such as working postures, lifting, carrying, quantitative demands, work pace, and emotional demands). This, in turn, was anticipated to lead to a decrease in physical exertion, musculoskeletal pain, and sickness absence (see Fig. 2).

2.4. The process evaluation framework

The process evaluation framework by Steckler and Linnan [16] was applied to gain insight into the extent to which the intervention was implemented as intended. This framework consists of a number of key process evaluation components: context, reach, dose delivered, dose received, fidelity, implementation and recruitment. In order to make an overall measure for implementation, we used the quantifiable implementation evaluation measuring dose delivered and dose received (participation and responsiveness) and fidelity inspired by Ferm and colleagues 2018 [32]. Table 1 lists the operationalization and data sources for the implementation measures.

2.5. Data collection and analysis

2.5.1. Questionnaires

2.5.1.1. *Manager questionnaires.* At baseline, 20-weeks follow-up and 40-weeks follow-up, an electronic questionnaire was sent to the managers of the 16 day nurseries. The questionnaires contained questions about the manager (e.g. personal characteristics and willingness to engage in the study), and characteristics of the day nursery (e.g. number of employees and number of children).

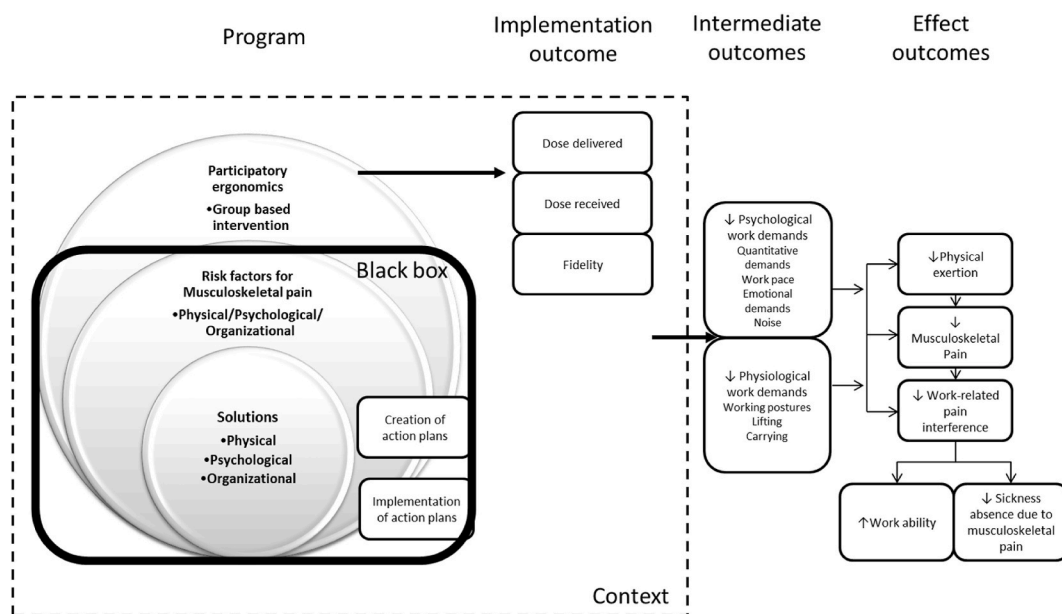


Fig. 2. The program logic illustrates the intervention (the program) and expected mechanisms and effects. In addition, the implementation outcomes (dose delivered, dose received and fidelity) is shown along with other process measures in the study, e.g. the context, the risk factors and solutions described in the action plans and implementation of action plans (part of the program logic has previously been published [26]).

Table 1
Operationalization and data sources for the implementation measures.

Process evaluation component as suggested by Linnan and Steckler [16]	Operationalization as suggested by Ferm et al. [32]	Data source
Dose delivered <i>Amount or number of intended units of each intervention or component delivered or provided by interventionists.</i>	Dose	Consultant questionnaire
Dose received <i>Extents to which participants actively engage with, interact with, are receptive to, and/or use materials or recommended resources; can include “initial use” and “continued use.”</i> <i>Participant (primary and secondary audiences) satisfaction with program, interactions with staff and/or investigators.</i>	Participation rate Responsiveness (satisfaction) Responsiveness (social support) Responsiveness (Intervention related social support) Responsiveness (motivation)	An independent observer, who filled in the lists of participants. Childcare workers questionnaire Childcare workers questionnaire Childcare workers questionnaire Consultant questionnaire
Fidelity <i>Extent to which intervention was implemented as planned.</i>	Content (Success criteria) Quality (Contribution to the participants' learning) Quality (Self-rated performance)	Consultant questionnaire Consultant questionnaire Consultant questionnaire

2.5.1.2. *Childcare workers questionnaires.* At baseline, 20-weeks follow-up and 40-weeks follow-up an electronic questionnaire was sent to the 190 childcare workers. The survey utilized established measures outlined in the quantitative implementation evaluation conducted by Ferm and colleagues in 2018 [32], specifically focusing on satisfaction and intervention-related support. Please refer to Table 1 for more details. Questions about satisfaction with the intervention consisted of six items. Participants were asked to rate their level of satisfaction on a scale of 1–5, with 1 being “to a very large extent” and 5 being “to a very small extent.” Similarly, the level of social support related to the intervention was assessed using four questions. Participants were asked to select their response from the categories “always,” “often,” “sometimes,” “seldom,” and “never.” To calculate a score, the Likert scale responses were transformed. The two most positive responses were assigned a score of 100, the two most negative responses were assigned a score of 0, and the middle response was assigned a score of 50.

2.5.2. Consultant questionnaires/logs

After each workshop, the consultant (4 in total) filled out a log that was created specifically for that workshop. This log was made to match the success criteria that were important for that particular workshop. The development of questions regarding the criteria for success was influenced by a quantitative evaluation method created by Ferm and colleagues in 2018 [32]. The consultants were given clear instruction that the logs were intended solely for analysis. The logs contained a combined total of 27 questions from all the workshops. Responses to the questions about the success criteria were sorted into four categories: “not implemented,” “partially implemented,” “fully implemented,” and “implemented more extensively.” The addition of the last category was intended to offer the possibility of gaining a deeper understanding of the implementation process. It acknowledged that a more thorough implementation of one topic could make up for a less thorough implementation of another topic [33]. As a result, scores of 100 were given to responses indicating “completely implemented” or “implemented more thoroughly” on the 4-point scale. A score of 50 was assigned to “partly implemented,” and “not implemented” received a score of 0.

The consultants evaluated the motivation of the participants after each workshop using a 5-point Likert scale with response options including “to a great extent,” “quite a bit,” “moderately,” “to some extent,” and “to a minimal extent.” This question has been utilized in

a research conducted by Ferm and colleagues [32] (refer to Table 1 for specifics regarding the phrasing of the inquiries).

2.5.3. Observations of workshops

Information on whether all the planned workshops were delivered and the number of participants present at each workshop was collected by an independent observer from the research group, who filled in the lists of participants. In addition to this, the observer also answered the exactly same questions as the questions posed in the consultant logs. This was to verify the quality of the consultants' responses to the questionnaires.

2.5.4. Action plans

The purpose of the action plan sheet was to facilitate the creation of action plans. The sheet included the following: 1) Theme, relating to one or two selected themes or situations from the pain mapping and prevention flower process; 2) What do we want to work with, relating to the specification of risk factors from chosen theme; 3) How will we do it, the solutions suggested by the team to address their prioritized risk factors; 4) How do we secure our good working postures, elaborating the solutions in terms of the aims of the intervention; 5) How do we see a change, describing the measurability of their suggested solutions; 6) Who should we cooperate with, considering whether they need to cooperate with others; and 7) When do we talk about how things are going, creating a timeframe and deadline for the action plan. Thus, it was possible to describe several risk factors and solutions in one action plan.

In addition, information on the presence of working teams at each workshop was based on the collection of action plans sheets and evaluation sheets, where the team names were registered.

The ratings of implementation success of the action plans were a part of the evaluation sheets. The purpose of the evaluation sheet was to make the working teams reflect on their work with the action plans, and provide explanations for their implementation success. The evaluation sheet included the following: 1) *Theme*, containing a brief description of the related action plans with suggested solutions; 2) *To what extent has the change succeeded*, containing an implementation rating on a scale from 0 to 10, with 0 being no implementation and 10 being full implementation; 3) *Description*, containing an explanation of the implementation rating and describing factors that impacted the process; and 4) *Tips to pass on*, containing experiences and advice that the team wanted to pass on to other teams in their day nursery.

2.6. Analyses

2.6.1. Quantitative analyses of implementation

For the analyses, we utilized SPSS (IBM SPSS Statistics for Windows, Version 22.0, IBM Corp, Armonk, NY). The inter-rater reliability between responses from the consultant logs and the observations by the researchers was examined using an intraclass correlation analysis and a Bland-Altman plot, revealing no discernible performance differences between consultants and observers (data not displayed). Consequently, the responses from the consultants' logs were employed to evaluate the fidelity of the intervention.

An implementation score, following the methodology outlined in Ferm and colleagues' 2018 study [32], was calculated. Implementation, encompassing fidelity, participation, and responsiveness, ranged from 0 to 100. ANOVA tests were utilized to explore the differences in implementation across workplaces and the time of intervention (intervention group vs wait-control group).

2.6.2. Categorization of action plans

Risk factors and suggested solutions were identified from the action plan sheets. Risk factors, risk situations (see appendix table A) and solutions, were categorized through visual inspection separately and all categorization processes followed these six steps: 1. Overview - grouping of printouts, 2. Initial categorization - first draft, discussion and agreement meeting, 3. Testing categorization - adjustments, new categories, 4. Descriptions and definitions - protocol/manual drafted, 5. Categorization - allocation of categories to action plans, and 6. Consensus - discussion on allocation disagreements. If we were not able to categorize a risk or a solution we had a category called unidentified.

Initially, a sample of approximately 100 action plans was printed, and the sample was then systematically divided into different initial categories based on their content. The initial categorization was performed by one of the researchers (MUD), and was followed by a discussion of the categories, with possible rewording, in a workgroup meetings with one or two other researchers (KGS and CNR). All members had to agree on the defined categories, however new categories could also be formulated. After the determination of the categories, they were tested in a new sample and descriptions of each category with examples were drafted as a manual for allocation, in order to ensure consensus. Both risk factor and solution categories were divided into three predefined main categories: physical, organizational, and psychosocial, which was inspired by the categorization in the study by Rasmussen and colleagues 2017 [10]. After the sub categories were finally defined, the allocation of action plans into categories was performed by two of the researchers working separately, with subsequent consensus meetings. Each action plan was tagged with categories of risk factors and solutions.

To estimate implementation success of action plans, implementation ratings of action plans from evaluation sheets were grouped into three implementation success levels: 1) No or low implementation success with ratings from 0 to 2, 2) Partial implementation success with ratings from 3 to 7 and 3) High implementation success countering ratings from 8 to 10, inspired by the study by Rasmussen and colleagues 2017 [10].

3. Results

3.1. Manager and nursery characteristics

Table 2 shows the baseline characteristics of the 16 managers and the day nurseries. The managers were on average 52 years and had been managers for 9 years. All managers expected to highly engage in the project. The day nurseries comprised two privately-owned and 14 public day nurseries. Half of them were characterized as being small (having 12 or less employees), and the average team count was four. Employments were both permanent and non-permanent, with an average of 14 permanent and three non-permanent childcare workers in each day nursery. Each nursery on average managed 54 children. Further information about the characteristics of the childcare workers can be found elsewhere [17].

3.2. Risk factors and solutions

3.2.1. Action plans characteristics

At the two first workshops, 127 action plan sheets were completed with a total of 369 action plans, equivalent to an average of 2.9 action plans per action plan sheet. 56 % of the action plans were created at the first workshop, and 44 % were created at the second workshop. A total of 23 action plans were excluded (12 in intervention group and 11 in wait-control group) because of missing data due to indeterminate handwriting and photos, resulting in 346 action plans in total forming the basis for further data analysis.

3.2.2. Identified risk factors

A total of 416 risk factors were identified. The categorization of risk factors resulted in 11 categories, which were placed into the three predefined main categories. The physical category comprised risks involving lifting/carrying, pushing/pulling, repeated movements, general working postures, and working postures related to the physical environment. The organizational category comprised risks involving lack of organization of daily tasks, lack of organization of personnel, and lack of organization of children. The psychosocial category comprised the risks involving time pressure, disturbance/noise, and parental behavior. Table 3 describes the characterizations of the risk factor categories.

There were 291 (70 %) risk factors within the physical category, 65 (16 %) within the organizational category, and 54 (13 %) within the psychosocial category. Within the physical category, the most prevalent risk factor category was general working postures with 122 (29 %) of total number of risks identified from action plans. The least prevalent physical risk factor categories involved pushing/pulling and repeated movements, with 5 (1 %) and 8 (2 %) respectively of the total number of risk. Within the organizational category, the most prevalent risk factor category was lack of proper organization of daily work tasks, with 29 (7 %) of all the risks identified. The least prevalent risk factor category was lack of proper organization of children, with 17 (4 %) risks included. Within the psychosocial category, the most prevalent risk factor category was interruptions/noise with 25 (6 %). The least prevalent risk category was negative parental behavior, with 7 (2 %) risks included. Table 6 also illustrates the prevalence of all the risk factor categories.

3.2.3. Suggested solutions

A total of 869 solutions from the action plans were divided into 17 categories, which were grouped within the three predefined guiding categories: physical, organizational and psychosocial solutions. The physical category comprised seven subcategories of solutions: *minimize lifting/carrying*, *working postures*, *physical environment*, *using assistive devices*, *make assistive devices available*, *using children's resources*, and *searching for knowledge*. The organizational category comprised six subcategories: *planning*, *organization of work tasks*, *group division*, *tools for planning*, *parental involvement*, and *communication*. Lastly, the psychosocial category comprised four subcategories: *allowing time*, *social support*, *ensuring calmness/quietness*, and *guidance/motivation*. Table 4 provides the characterization of each subcategory. The majority of the solutions were in the physical category with 528 (61 %) solutions. The remaining solutions were distributed almost equally between the organizational and psychosocial categories, with 177 (20 %) and 164 (19 %) solutions,

Table 2

Manager and nursery characteristics. Data are percentages/numbers (N) and mean/standard deviation (SD).

	Intervention group N = 8		Wait-control group N = 8		Total N = 16	
	% (N)	Mean (SD)	% (N)	Mean (SD)	% (N)	Mean (SD)
Manager characteristics (N = 16)						
Age (years) (n = 15)		53 (7)		51 (9)		52 (8)
Seniority in current position (years) (n = 15)		11 (6)		7 (6)		9 (6)
High engagement in the project (n = 13)	100 % (5)		100 % (8)		100 % (13)	
Nursery characteristics (N = 16)						
Private day nurseries	25 % (2)		13 % (1)		13 % (2)	
Public day nurseries	75 % (6)		88 % (7)		88 % (14)	
Size (small \geq 12 employees)	38 % (3)		63 % (5)		50 % (8)	
Working teams (average)		4 (1)		5 (1)		4 (1)
Permanent childcare workers		14 (6)		15 (7)		14 (6)
Non-permanent childcare workers		4 (2)		3 (4)		3 (6)
Children in the nursery		53 (16)		55 (18)		54 (16)

Table 3
Categories of identified risk factors and their definitions.

Risk factors		
Category of identified risk factors	Definition of risk factor category	Total (N = 416) n (% of total)
Physical	Working postures - in general	Physically stressful and inappropriate working postures, or unnecessary physical work demands due to the children's lack of self-reliance
	Lifting/carrying	Lifting or carrying of children or heavy objects
	Working postures - physical environment	Working positions that are affected by the physical environment related to accessibility, range or location of devices or furniture
	Repeated movements	Light or moderate workload that entails physical stress at longer duration
	Pushing/pulling	Pushing or pulling of children or heavy objects
Organizational	Poor organization of daily work tasks	Challenges that relate to routines, workflows, times, preparation and actions of a practical nature
	Lack of proper organization of personnel	Challenges in work procedures, roles, or work organization
	Lack of proper organization of children	Challenges in relation to the children's group, such as the division of children or focus on specific children
Psychosocial	Interruptions/noise	Identification of nuisance noise, lack of calmness or interruptions
	Time pressure	Lack of time or identification of stressful circumstances or situations
	Negative parental behaviour	Relates to negative parental behaviour and actions or lack thereof
Unidentified	None of the above	
		291 (70 %)
		122 (29 %)
		105 (25 %)
		51 (12 %)
		8 (2 %)
		5 (1 %)
		65 (16 %)
		29 (7 %)
		19 (5 %)
		17 (4 %)
		54 (13 %)
		25 (6 %)
		22 (5 %)
		7 (2 %)
		6 (1 %)

Table 4
Categories of solutions and their definitions.

Solutions		
Category of suggested solution	Definition of solution category	Total (N = 869) n (% of total)
Physical	Using children's resources	Increase children's self-reliance to replace or reduce physical workload
	Using assistive devices	Use of assistive devices to reduce physical workload or to enable the children to become more self-reliant
	Working postures	Alternative working postures or use of postures to reduce physical workload.
	Physical environment	Involvement of or change to physical environment to reduce physical workload
	Minimizing lifting/carrying	Reduce the amount of lifting/carrying of children or furniture
	Assistive devices available	Accessibility related to location of existing assistive devices or to the acquisition of new assistive devices
	Searching for knowledge	Seek knowledge concerning correct ergonomics
Organisational	Group division	Divide children (and staff) into smaller groups or change existing group divisions
	Parental involvement	Improve cooperation with the parents
	Planning	Change in practical tasks, times and general planning of the day
	Organisation of work tasks	Organise and distribute work tasks and/or responsibilities
	Communication	Better communication both within teams, between teams and with the management
Psychosocial	Tools for planning	Compilation or use tools and materials to improve planning or organisation of work
	Social support	Kind/friendly/supportive feedback to each other, both internally and across teams
	Guidance and motivation	Practice, guide or motivate the children to become more self-reliant
	Ensuring calmness/quietness	Reduce noise and/or create calmness, both in relation to children and surroundings
	Allowing time	Prioritize or create time in an activity or situation. This relates both to finding time to do something different and to avoiding stressful situations
		528 (61 %)
		169 (19 %)
		94 (11 %)
		94 (11 %)
		91 (10 %)
		44 (5 %)
		34 (4 %)
		2 (0 %)
		177 (20 %)
		42 (5 %)
		44 (5 %)
		35 (4 %)
		30 (3 %)
		16 (2 %)
		10 (1 %)
		164 (19 %)
		57 (7 %)
		44 (5 %)
		36 (4 %)
		27 (3 %)

respectively. Within the physical category, the most prevalent solution category was *using children's resources* with 169 (17 %) solutions, followed by *working postures* and *using assistive devices* which each included 94 (11 %) solutions. The least prevalent solution category within the physical category was *searching for knowledge* with 2 (0.2 %) solutions.

3.2.4. Suggested solutions linked to identified risk factors

We mapped the suggested solutions to their risk factors, based on the three main categories (physical, organizational, or psychosocial) (data not shown – see Appendix table B). 80 % of all the solutions addressed physical risk factors, 11 % addressed organizational risk factors and the last 9 % addressed psychosocial risk factors.

3.3. Implementation of action plans

3.3.1. Implementation success

At the second and third workshops, 123 evaluation sheets were completed. There was a total of 299 implementation ratings of action plans, amounting to an average of 2.4 evaluations per evaluation sheet. 51 % of the evaluations were created at the second workshop and 49 % at the third workshop. There were 19 % of the action plans that had no implementation rating. None of the evaluations of action plans were excluded.

In total, 51 % of the 299 evaluations had a rating of 8 or higher, meaning that the implementation was highly successful, 34 % had a rating between 3 and 7, meaning that the implementation was partly successful, and 15 % had a rating between 0 and 2, meaning that there was no implementation or the implementation was poor.

3.3.2. Solutions linked to implementation success

The matching of action plans with the evaluation of action plans resulted in 594 suggested solutions with an implementation rating. This means that 32 % of the solutions had no implementation rating. The implementation success is linked to the overall action plan which could include more than one solution, meaning that there are more solutions with an implementation rating than implementation ratings of actions plans. 43 % of the physical solutions were implemented highly successfully, 40 % were implemented partly successfully, and 16 % were either not implemented or implemented unsuccessfully. 47 % of the organizational solutions were implemented highly successfully, 43 % were implemented partly successfully, and 10 % were either not implemented or implemented unsuccessfully. 38 % of the psychosocial solutions were implemented highly successfully, 52 % were implemented partly successfully, and 10 % were either not implemented or implemented unsuccessfully (see Fig. 3).

The implementation score from 0 to 10 was divided into: High implemented: 8–10, Partly implemented: 3–7, No or low implemented: 0–2.

3.4. Implementation of intervention

3.4.1. Dose delivered

All three participatory ergonomics workshops were conducted at all 16 day nurseries, resulting in a dose delivery rating of 100 % (Table 5). A majority of the working teams were present at all three participatory ergonomics workshops: a total of 63 (89 %) teams were present at the first workshops (workshop 1), while 64 (90 %) and 59 (83 %) teams were present at the second and third workshops (workshops 2 and 3), respectively.

3.4.2. Implementation

The overall fidelity of the intervention was 83 %, with each of the three individual workshops ranging from 82 % to 84 %. The exposure rate for the entire intervention was 56 %, and the responsiveness was 83 %. The mean participation rate was 68 %. The final implementation score for the total intervention was 47 %, and for workshop 1–3, the implementation score was 53, 43, and 42 %, respectively. For more information see Table 6.

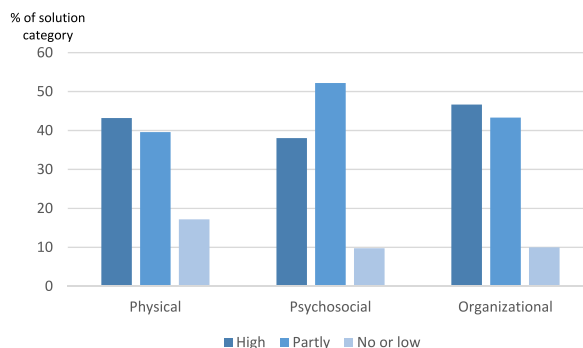


Fig. 3. Implementation of solutions within each of the three main categories: physical, organizational and psychosocial.

Table 5

Dose delivered and dose received of each of the three workshops and the total intervention at organizational level.

	Workshop 1		Workshop 2		Workshop 3		Total intervention	
	n	(%)	n	(%)	n	(%)	n	(%)
Dose delivered (workshops conducted)	16	100 %	16	100 %	16	100 %	48	100 %
Dose received (teams present)	63	89 %	65	90 %	59	83 %		

Table 6

The total implementation score for the three workshops and the total intervention. The implementation consists of fidelity, responsiveness and participation.

	Workshop 1			Workshop 2			Workshop 3			Total intervention		
	N	Mean (%)	SD	N	Mean (%)	SD	N	Mean (%)	SD	N	Mean (%)	SD
Fidelity	148	84	5	122	82	4	117	82	4	76	83	3
Content (success criteria)	148	98	4	122	95	6	117	96	6	76	97	3
Quality (performance)	148	77	9	122	75	5	117	76	5	76	76	4
Contribution	148	78	7	122	75	0	117	75	1	76	76	2
Overall self-rated performance	148	75	10	122	75	9	117	76	8	76	76	6
Exposure	190	65	4	190	52	3	190	50	2	190	56	2
Content (success criteria)	190	76	3	190	61	4	190	59	3	190	66	2
Quality (performance)	190	60	7	190	48	3	190	46	3	190	51	4
Contribution	190	61	5	190	48	0	190	46	1	190	51	2
Overall self-rated performance	190	59	8	190	48	6	190	46	5	190	51	5
Responsiveness	66	82	12	52	82	12	60	83	13	37	83	13
Satisfaction	71	88	15	68	87	15	68	87	16	56	89	16
Social support	109	87	24	109	87	24	109	87	24	109	87	24
Motivation	148	77	15	122	75	8	116	76	15	76	76	8
Participation	190	78	42	190	64	48	190	61	49	190	68	33
IMPLEMENTATION	66	53	9	52	43	7	60	42	7	37	47	8

3.4.3. Implementation across nursery characteristics and timing of intervention

Table 7 displays the outcomes of the implementation components concerning nursery characteristics (private/public and size) and the timing of intervention (intervention rounds). Regarding delivery timing, significant differences were observed in fidelity ($p = 0.000$), exposure ($p = 0.000$), participation ($p = 0.029$), responsiveness ($p = 0.024$), and overall implementation (0.002). No significant variations in these components were identified between private and public workplaces. However, concerning workplace size, a numerical distinction emerged (though not statistically significant, $p = 0.065$) in participation, with smaller workplaces exhibiting lower participation compared to their larger counterparts.

4. Discussion

This study aimed to gain insight into the “black box” and the implementation of a participatory ergonomics intervention among childcare workers by identifying perceived risks and suggested solutions to work-related musculoskeletal pain from the intervention. The primary findings were that most of the perceived risk factors were categorized as physical (70 %) and most of the suggested solutions fell within the physical category (61 %). About half (51 %) of the action plans showed high implementation success. Of 16 workshops, 100 % were delivered with a fidelity of 83 %. Average participation, exposure, responsiveness and implementation were 68 %, 56 %, 83 % and 47 %. The implementation differed for timing of intervention.

4.1. Risk and solutions

The majority of the perceived risk factors were categorized as physical relating to working postures (29 %) and lifting/carrying (25 %). This may be unsurprising as the focus of the participatory ergonomics intervention was on physical parameters such as improving ergonomics and reducing musculoskeletal pain and physical exertion. Traditionally, reduction of work-related musculoskeletal pain has focused on working postures and heavy lifting [34]. However, more recently it has become acknowledged that ergonomic issues are related not only to physical factors, but also to organizational and psychosocial [5,10,30]. The findings of the current study also show that ergonomic risk factors related to organizational or psychosocial issues are present among childcare workers. More specifically, 39 % of the risk factors were characterized as organizational or psychosocial. This is comparable to a study on nurses' aides that also found that 31 % of risk factors in an ergonomic intervention were organizational or psychosocial [10]. Consequently, ergonomic interventions should not only focus on physical risk factors but include organizational and psychosocial factors.

As with the risk factors, most of the suggested solutions fell within the physical category (61 %) e.g., using the resources of the children by encouraging self-reliance, using assistive devices, and using correct or alternative working postures. Thus, many of the solutions were suggested in the same category as their associated risk factor. This is different from other participatory ergonomic

Table 7

implementation components across delivering timing and workplaces (private/public and size). n = number of participants (childcare workers) within each category, SD=Standard Deviation.

	DELIVERY							RECEIPT						IMPLEMENTATION						
	Fidelity			P-value	Exposure			P-value	Participation rate			P-value	Responsiveness			P-value	Implementation			P-value
	n	mean	SD		N	Mean	SD		n	mean	SD		n	mean	SD		n	Mean	SD	
Timing of intervention				0.000				0.000				0.029				0.024				0.002
Intervention group	43	84	3		96	57	2		96	73	29		14	89	8		14	51	6	
Wait-control group	33	81	3		94	55	1		94	62	36		23	79	14		23	44	8	
Workplaces (type)				0.223				0.385				0.828				0.919				0.915
Private	12	84	1		12	57	1		38	67	31		3	84	12		3	47	6	
Public	64	83	3		64	56	2		152	68	34		34	83	13		34	47	8	
Workplaces (size)				0.151				0.200				0.065				0.382				0.587
Small	25	82	2		25	56	2		73	62	4		10	86	10		10	48	6	
Large	51	83	3		51	56	2		117	71	3		27	82	13		27	46	8	

studies, which identified solutions more concerned with organizational and individual issues [10,30]. However, in the current intervention we asked the childcare workers specifically to focus on solutions that were close to their core task, e.g. using the resources of the children by encouraging self-reliance [35,36]. Since such solutions were categorized as physical, we might see a larger proportion of solutions within this category than the other comparable studies. Many participatory ergonomic interventions also involve the managers [6], and therefore solutions may be more related to organizational issues. In the current study, the managers did not participate in the participatory process which may partly explain the smaller number of suggested organizational solutions (20%). Villumsen and colleagues [37] found that social support, which is included in the psychosocial category in the current study, had a modifying effect on low back pain in relation to physically demanding working postures. In the current study, social support comprised only 7% of the suggested solutions however, with the growing focus on organizational and psychosocial aspects of musculoskeletal pain [38,39] future studies that aim to reduce musculoskeletal pain may explore this further. Overall, participatory ergonomic interventions are typically complex and diverse and should be proposed in a variety of areas to have a positive effect on musculoskeletal pain [40,41].

4.2. Implementation of action plans

Previous participatory ergonomic studies that used self-reported evaluations on implementation found implementation success ranging from 33% to 38% [8,10,12,42]. The high implementation success in this study may be caused by the instruction that solutions should be an integrated part of the core tasks, which has previously been recommended to improve participatory implementation/interventions [43,44]. Another factor may be that the action plans primarily included small adjustments to the existing work, thus increasing fidelity [22]. Implementation success was distributed almost equally across physical (43%) and organizational (47%) solutions. Other studies have found highest level of implementation success within organizational solutions and lower implementation success within physical solutions [10,30]. The results of the current study thus indicate that the solutions developed by the participants in this study relating to physical issues may be more practical and easier to follow.

4.3. Implementation of intervention

Of 16 workshops, 100% were delivered with a fidelity of 83%. The overall high fidelity indicates that the intervention was delivered as intended and therefore a viable assessment of its contribution to the effectiveness outcome may be made. Average participation, exposure, responsiveness, and implementation were 68%, 56%, 83% and 47%. The results are comparable to another participatory ergonomic study [32], which found similar results; fidelity 92%, participation 66%, exposure 63%, responsiveness 90% and implementation 60%. For timing of intervention (intervention rounds) there was a significant difference in fidelity, exposure, participation, responsiveness, and implementation. This could indicate a learning effect for the ergonomic consultants over time. Moreover, for workplace size there was a numeric difference in participation, where the small workplaces had lower participation compared to the larger workplaces. The results show that timing of interventions and contextual factors affect implementation. However, to fully understand the significance of these factors, further identification of the subcomponents are needed. Additionally, qualitative evaluation may reveal more valuable knowledge on the barriers and facilitators of the implementation success.

4.4. Strengths and limitations

A main strength of this study was the detailed description of the participatory ergonomic intervention and data analysis, making the study transparent and enhancing reproducibility. The large amount of data at several levels; the quantification of the semi-qualitative data from the action plans and ratings from evaluation and implementation sheets makes exploration and analysis of the “black box” possible. Consequently, the results of this study may strengthen the interpretation of the results of the effectiveness of the participatory ergonomics intervention.

A limitation of this study was that the action plans sheets were not developed explicit to the purpose of this study, opening the possibility of misinterpretation of the identified risk factors. The evaluation sheets containing implementation barriers and facilitators were not analyzed in this study. This could possibly have revealed an extra layer of the “black box”. Lastly, only 68% of the action plans and evaluation sheets were included in the analysis of implementation rating due to indeterminate handwriting and photos and difficulties matching the implementation rating with the solutions.

4.5. Perspectives

Future participatory ergonomic studies should include identification of content and implementation details as this may reveal essential knowledge as why or why not an intervention is effective. No golden standard or validated framework exist for gaining this knowledge; however, it is recommended that future studies should try to include much more elaborate implementation details, as this may ensure consensus and reliability. Moreover, future studies could consider to apply risk management strategies in the analysis, including proactive and reactive measures, to map the solution structures and get information about the management strategies used in childcare.

5. Conclusions

This study identified and described the content, i.e., perceived risks and suggested solutions, and implementation of the participatory ergonomic intervention (the “black box”) among childcare workers in 16 day nurseries (the TOY project). Perceived risks and suggested solutions from action plans could be allocated to physical, organizational, and psychosocial categories. Both implementation of action plans and overall implementation fidelity of the participatory intervention were high. Our findings revealed that the timing of intervention delivery significantly influenced fidelity ($p = 0.000$), exposure ($p = 0.000$), participation ($p = 0.029$), responsiveness ($p = 0.024$), and overall implementation ($p = 0.002$). Moreover we found that the size of workplace could potentially influence participation, where small workplaces had a lower participation compared to the larger workplaces (although not significant $p = 0.065$). This study showed that participatory ergonomic interventions are complex and diverse and should focus on physical, organizational and psychosocial factors to have a positive effect. We believe that the findings of this study can inspire and improve future participatory ergonomics interventions.

5.1. Ethics statement

The Danish National Committee on Biomedical Research Ethics (the local ethics committee of Frederiksberg and Copenhagen) has evaluated a description of the study and concluded that, according to Danish law as defined in Committee Act § 2 and § 1, the intervention described should not be further reported to the local ethics committee (reference number 16048606). All participants signed an informed consent before the first measurement.

Funding

The study is externally funded by The Danish Working Environment Research Fund (grant no. 2-2016-03 20165101186).

Data availability

The data associated with our study has not yet been deposited into any publicly available repository. It will however be made available upon request.

CRedit authorship contribution statement

Maja Schönheyder: Writing - original draft, Methodology, Formal analysis. **Mikala Utzon Dietz:** Writing - review & editing, Visualization, Methodology, Formal analysis. **Kathrine Greby Schmidt:** Writing - review & editing, Methodology, Formal analysis. **Malene Jagd Svendsen:** Writing - review & editing, Investigation. **Ole Henning Sørensen:** Writing - review & editing, Methodology, Conceptualization. **Andreas Holtermann:** Writing - review & editing, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization. **Charlotte Diana Nørregaard Rasmussen:** Writing - review & editing, Visualization, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We would like to acknowledge Klaus Hansen, Dorte Ekner, Jørgen Skotte, Pernille Kold Munch and the TOY-projects' student helper team for their effort during the data collection period.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.heliyon.2024.e24167>.

Appendix

Risk situations

The situations related to risk factors identified from action plans resulted in 11 risk situation categories. The 11 risks situation categories were as follows: changing diaper, other bathroom activities, sleeping, clothing, cleaning, transition, drop-off, eating/group gathering, comforting, play, and break. Short characterizations of the categories are described in table A. The most frequent risk situations were *sleeping* with 72 (21 %), *clothing* with 62 (18 %), and *changing diaper* with 59 (18 %), out of a total of 337 situations identified. A minority of action plans identified *breaks* with 2 (1 %), *play* and *drop-off* with 5 (1 %) and 13 (4 %) action plans

respectively, as the relevant risk situation. Nine action plans could not be allocated to a risk situation category.

Table A

Categorization and characterisation of situations. Situations were identified from action plans and stratified in 11 situation categories. A total of 337 situations were identified and nine action plans were unable to identify situations to.

Situation Categories	Characterisation of situation categories	Total (N = 337)
		n (% of total)
Sleeping	Actions that take place in the crib room or relate to the children's sleep	72 (21 %)
Clothing	Actions related to getting clothes on or off or other situations in the wardrobe	62 (18 %)
Changing diaper	Actions that take place at the changing table	59 (18 %)
Cleaning	Actions related to cleaning up or cleaning, either toys or after meals	39 (12 %)
Other bathroom activities	Actions that take place in the bathroom besides at the changing table	22 (7 %)
Eating/Group Gathering	Meal situations or group gatherings in the childcare unit	19 (6 %)
Comforting	Comforting when a child is upset or sad	17 (5 %)
Transition	The transition or shift from one situation to another	18 (5 %)
Drop-off	Parents either drop off or pick up their children	13 (4 %)
Unidentified	Others than the above	9 (3 %)
Play	Play and other activities where children and childcare workers are sitting on the floor or staying in the play area	5 (1 %)
Break	Need of break for a single child or several children	2 (1 %)

Solutions mapped to risk factors.

Most of the physical risk factors also had physical solutions (73 %), whereas 12 % and 15 % were organizational and psychosocial solutions, respectively. Within organizational risk factors, 75 % of the solutions were organizational, whereas physical and psychosocial solutions counted 12 % and 13 % respectively, of the total number of solutions. Within the psychosocial risk factors, 68 % of the solutions were psychosocial, 25 % were organizational and 9 % were physical solutions. See table B.

Table B

Main categories of suggested solutions mapped to main categories of identified risk factors.

RISK FACTORS	SOLUTIONS					
	Physical (N = 528)		Organizational (N = 164)		Psychosocial (N = 177)	
	N	%	N	%	N	%
Physical (N = 291)	503	73	83	12	101	15
Organizational (N = 54)	12	12	75	75	13	13
Psychosocial (N = 65)	9	7	2	25	6	68

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