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Feasibility of Training Occupational Safety and Health Professionals in Musculoskeletal Disorders Intervention Delivery: A Mixed-Methods Study

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Title

Feasibility of Training Occupational Safety and Health Professionals in Musculoskeletal Disorders Intervention Delivery: A Mixed-Methods Study

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Abstract

Background

Musculoskeletal disorders (MSD) impose substantial individual and societal costs. Workplace interventions targeting MSD are often delivered by occupational safety and health (OSH) professionals but with little guidance. Alongside a newly developed multicomponent workplace intervention for MSD, PATH@work, we designed a train-the-trainer delivery strategy and training course aiming to enable OSH professionals to deliver the intervention. This study aimed to evaluate the OSH professionals' attitudes towards MSD and perceived delivery skills, explore their perceptions of and experiences with the training course and intervention delivery, and identify potential modifications of the training course.

Methods

We carried out a mixed method convergent study design. Ten OSH professionals completed the training course, of whom four delivered PATH@work at their workplaces followingly. Attitudes towards MSD and perceived delivery skills were assessed using questionnaires before and after training. Intervention delivery was evaluated through logbooks and self-reported delivery satisfaction (0-10 scale). Experiences of the training course and delivery were explored through a focus group and semi-structured interview guided by the Theoretical Framework of Acceptability. Quantitative data were analysed descriptively, qualitative data using the Framework Method, and mixed method analysis developed meta-inferences and identified relevant modification of the training course.

Results

Most OSH professionals (n=7, 77.8%) agreed that psycho-social factors can contribute to MSD, and 75% (n=6) reported having the necessary tools to deliver the intervention after the training course. Delivery of intervention modules varied (33-100%), while mean delivery satisfaction was high (8.1). Three themes emerged: 1) positive psycho-social effects of the physical exercises, 2) role uncertainty among the OSH professionals, and 3) the need for organisational support. Participatory ergonomics was perceived as

particularly challenging, highlighting the importance of organisational engagement. These findings informed revisions to the training course.

Conclusion

The OHS professionals possessed knowledge consistent with a biopsychosocial understanding of MSD and the core messages of the intervention before the training. Although questionnaire responses suggested confidence in delivering PATH@work, qualitative findings indicated that the training did not sufficiently develop the competencies needed to implement all intervention components or facilitate workplace change. Future training should place greater emphasis on technical facilitation, relational competencies, and organisational change skills.

Trial registration

ClinicalTrials.gov NCT07466680. Registered 03/03/2026. This study is retrospectively registered.

Keywords

Musculoskeletal pain; train-the-trainer; education; occupational health; work environment; health literacy; physical exercises; participatory ergonomics

Background

Musculoskeletal disorders (MSD) constitute the leading cause of disability worldwide, affecting approximately 1.7 billion individuals (1). MSD is associated with substantial individual consequences, including pain, impaired functional capacity, and reduced workability. At the societal level, MSD imposes considerable economic costs through increased health care use, sickness absence, and premature exit from the labour market (2-4). In Denmark, national surveys indicate that almost 30% of employees experience recurrent pain in the back, neck, and shoulders, with a higher prevalence among those with physically demanding work (5). The World Health Organization prioritises the prevention of MSD among high-risk occupational groups and identifies the workplace as a key setting for interventions aimed at improving worker health and sustaining labour market participation (6).

Occupational Safety and Health (OSH) professionals are trained specialist who work to protect and promote a healthy work environment. They are often involved in implementing new workplace interventions using train-the-trainer (or cascading) strategies (7), where facilitators (e.g. researchers or consultants) transfer knowledge and skills to enable OSH professionals to deliver interventions to a target group (8, 9). This approach has been effective in disseminating knowledge in healthcare settings (10, 11), and can reduce reliance on external experts while enhancing intervention sustainability (12).

The train-the-trainer multilevel model aligns well with OSH principles, emphasising the importance of worker engagement and peer-learning in supporting collective organisational interventions. Participatory approaches involving workers in identifying physical and psycho-social risk factors have been proposed to support the OSH professionals in a more integrated risk assessments, particularly in MSD prevention (13, 14). Furthermore, participatory and context-specific implementation processes involving managers and OSH professionals have been shown to facilitate intervention uptake (15) by creating collective ownership

and a supportive workplace environment (16). However, OSH professionals have called for clearer implementation guidelines and deeper understanding of participatory intervention components (7, 13).

In 2024, we designed a workplace intervention targeting MSD, PATH@work, consisting of 15 half-hour modules with components to increase worker musculoskeletal health literacy, physical exercises and participatory ergonomics to be delivered over an 8-week period (17). Alongside the intervention, we designed a train-the-trainer delivery strategy and developed a one-day training course aiming to enable OSH professionals to deliver the multicomponent PATH@work intervention.

Prior to a full-scale implementation and effectiveness trial, rigorous evaluation of the training course content, structure and methodologies is recommended this strategy to foster favourable intervention outcomes (18). Therefore, we conducted a mixed-method feasibility study to evaluate the training course and the following intervention delivery. Specifically, we aimed to:

1. evaluate the OSH professionals' attitudes towards MSD and perceived delivery skills before and after the training course
2. explore the OSH professional's perceptions of and experiences with the training course and intervention delivery
3. identify potential modifications of the training course by comparing and integrating quantitative and qualitative data.

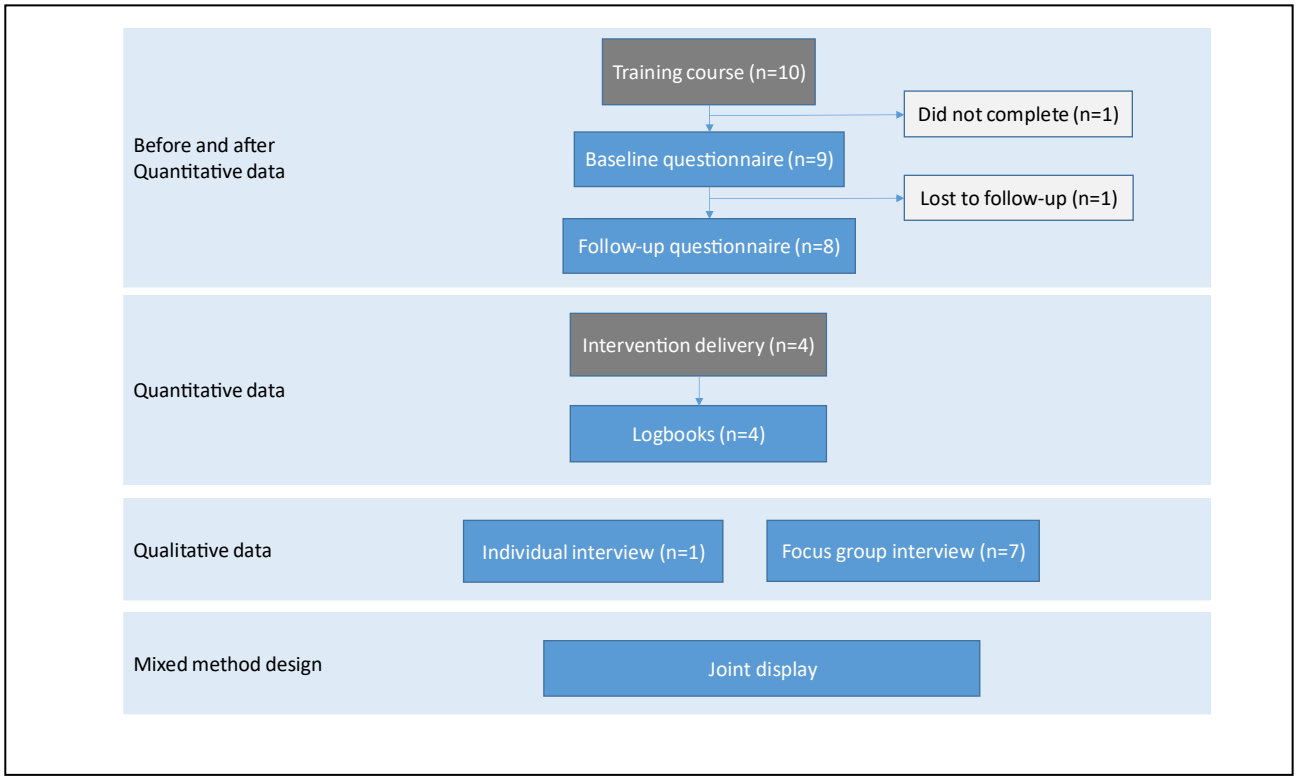
Methods

Design

We employed a convergent parallel mixed methods design, in which quantitative and qualitative data were

collected at the same time, analysed separately, and then compared and integrated (19, 20). Data were collected from April to June 2025. Quantitative data were collected before and after the training program using questionnaires to evaluate the OSH professionals' attitudes towards MSD and their perceived skills at delivering the intervention. Moreover, the OSH professionals completed logbooks during the intervention period, recording their delivery of the PATH@work intervention. Further, we used qualitative interview data to in-depth explore the OSH professionals' perceptions of and experiences with the training course and intervention delivery. The collection of both quantitative and qualitative data allowed for a more complete and comprehensive understanding of the training course impact and intervention delivery. Finally, we integrated the data in a joint display to identify potential modifications of the training program and areas of improvement (Figure 1).

Figure 1. Flow diagram of the participants, study design and data collection.



The dark grey boxes illustrate what the OSH professional evaluate. The blue boxes illustrate quantitative and qualitative data collection and the two data sources (questionnaires, logbooks and interviews) used for the mixed method analysis

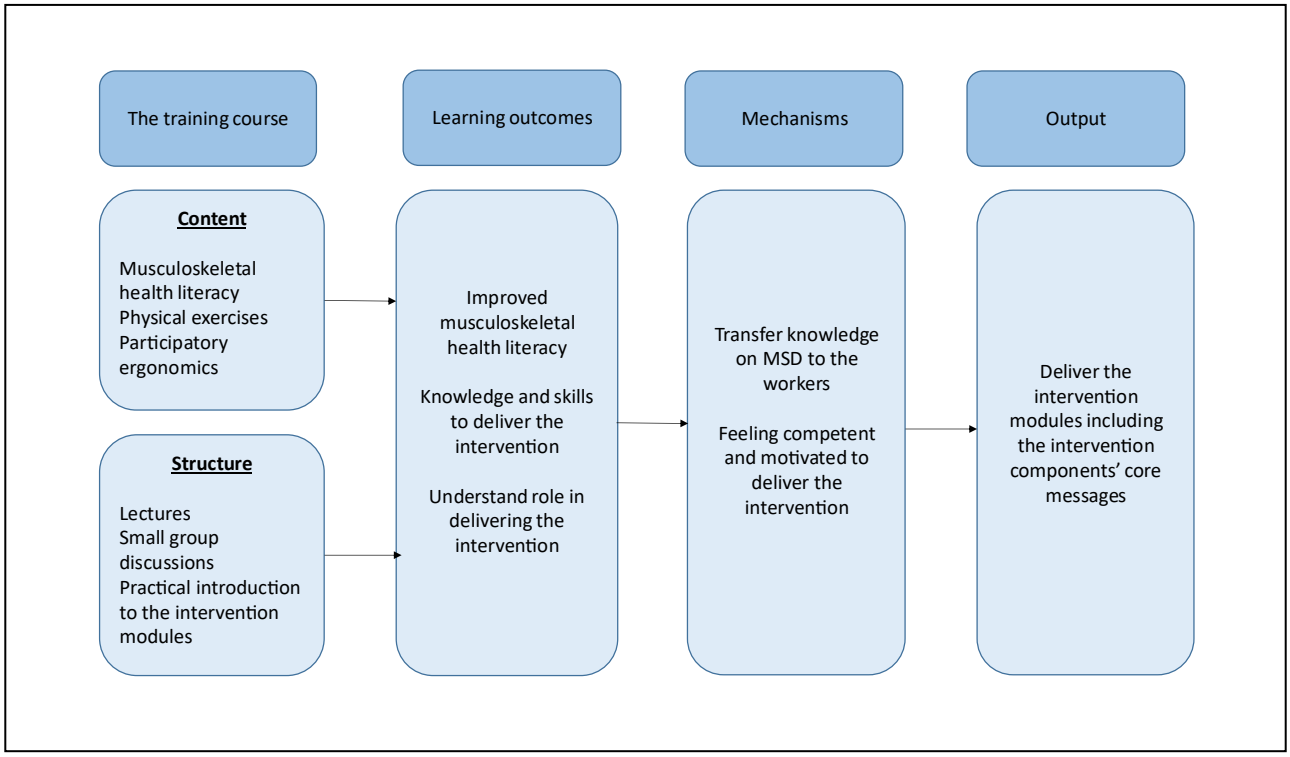
Setting and recruitment

We recruited OSH professionals from four Danish workplaces in sectors characterised by physically demanding work tasks through collaboration with a health insurance company and by posting on LinkedIn. Three of the included workplaces were large production companies, and one was a contracting company for infrastructure projects. Following the training course, the PATH@work intervention was delivered to an appointed work team at each workplace.

The training course, course participants and intervention delivery

The one-day training course for the OSH professionals was held at the researchers' workplace in April 2025, facilitated by three members of the research team (MS, SVS, and SBJ). The training course content was musculoskeletal health literacy, physical exercises and participatory ergonomics, and aimed at upgrading the knowledge, skills, and competencies of OSH professionals in delivering the components and core messages of the PATH@work intervention. This included ensuring the OSH professionals felt competent and motivated to transfer the knowledge to workers, and understood their role in the intervention. The didactic methods were lectures, small-group discussions, and a practical introduction to the intervention components (Figure 2).

Figure 2. The training course and the proposed effect mechanisms



MSD =musculoskeletal disorders

Six in-house OSH professionals and two OSH representatives (employee-elected) from the four workplaces, and two OSH professionals employed at the health insurance company (out-house consultants), totalling 10 individuals, participated in the training course. Four of the OSH professionals had professional backgrounds as physiotherapists; however, none of the four were responsible for the subsequent delivery of the intervention at the four workplaces. Ultimately, two OSH professionals from each of two companies and two OSH representatives from the other two companies, supported by one of the out-house consultants, delivered the 15-module, 8-week PATH@work intervention (Supplementary file 1).

Quantitative data collection

Pre- and post-training course attitudes towards MSD and delivery skills

Data were collected one week prior to participating in the training course and immediately after the training course. Before the training course, the OSH professionals received a link to an electronic

questionnaire, inquiring about their gender, professional background, and attitudes towards MSD. The questionnaire was developed by the research group with inspiration from the GLA:D® back program (21) and covered three domains (Supplementary file 2). The first contained four statements eliciting the OSH professionals' attitudes towards MSD, for example, *psycho-social factors can contribute to MSD without physical injury*. The second domain contained eight statements, eliciting the OSH professionals' attitudes towards organisational prevention of MSD, for example, *preventing MSD at the workplace involves the individual worker, the team, the management, and upper management.* Each of the statements was scored on a 6-point Likert scale with the following response options: "completely agree", "partly agree", "slightly agree", "slightly disagree", "partly disagree", and "completely disagree".

In the post-training course questionnaire, we developed a third domain (Supplementary file 3) pertaining to the OSH professionals' self-perceived intervention delivery skills evaluated using four statements, for example, *I feel comfortable delivering the intervention.* Three statements were scored on a 5-point Likert scale with the response options "completely agree", "agree", "neither agree nor disagree", "disagree", and "completely disagree". The last statement, *I feel prepared to deliver the intervention*, was scored on a 3-point Likert scale "very well prepared", "well prepared", and "neither well nor poorly prepared".

Intervention delivery

Delivery of the PATH@work intervention was assessed using online logbooks completed by the OSH professionals after each intervention module. We developed the logbooks for this study and included six items: the number of modules delivered, the number of workers and managers present per module, the number of modules delivered within half an hour, self-assessed core message delivery success, and the overall satisfaction with the module delivery on an 11-point numerical scale (0-10) with higher scores indicating higher success or satisfaction with intervention delivery (Supplementary file 4).

Quantitative data analysis

We used simple descriptive statistics to analyse the data and reported the numbers and proportions, or means as appropriate. Data were analysed in the statistical software R.

Qualitative data collection

Exploring the training course and delivery strategy

To explore the OSH professionals' perceptions of and experiences with the training course and delivery of the intervention, qualitative data were collected through a focus group interview with seven of the ten course participants and one individual, semi-structured face-to-face interview. All four deliverers of the intervention participated in the interviews. The interview guide was structured using The Theoretical Framework of Acceptability (TFA) (22) (Supplementary file 5). The TFA comprises eight constructs (affective attitude, burden, perceived effectiveness, ethicality, intervention coherence, opportunity costs, self-efficacy, and general acceptability), reflecting acceptability as a multi-faceted construct that captures the extent to which individuals delivering or receiving an intervention consider it appropriate (23). MS carried out the interviews, which were audio-recorded, transcribed verbatim, and pseudonymised using Dictus AutoScribe.

Qualitative data analysis

Data were analysed using the Framework Method (24, 25). The analytic steps were: 1) familiarisation of the data through reading the transcript and listening to the audio files to gain an overview of the data coverage, 2) indexing data into initial codes and sub codes using the TFA framework but with openness to new codes to develop the initial coding tree, 3) summarising the data for each code maintaining meaning and context from the original data, 4) abstraction and interpretation of the data summaries to detect and identify main elements, 5) summarising the detected main elements into key dimensions, and 6) categorising the key dimensions into themes and subthemes. The first author carried out the initial data analysis using the NVivo 15 (version 3) software, and subsequently, the results were discussed within the

research group to clarify codes and themes, and to reach consensus. and analysed. Finally, illustrative quotes were translated into English.

Integration of findings

We used joint displays to organise the quantitative and qualitative findings and identify links and patterns between the two sets of data (20, 26). When integrating the quantitative and qualitative findings, we dichotomised the quantitative responses into agree ("completely agree", "partly agree" and "slightly agree") and disagree ("completely disagree", "partly disagree" and "slightly disagree"). Firstly, we compiled the quantitative and qualitative data into meaningful units, searching for immediate links between the two datasets. Secondly, we compared and contrasted the quantitative and qualitative findings to establish relationships using the labels: *convergence, divergence, and expansion.* Lastly, we identified areas of complementarity, defined as new insights or interpretations based on the integrated findings, forming meta-inferences and identifying potential modifications for the future training course.

Results

Quantitative results

Pre- and post-training course attitudes towards MSD

The majority of the OSH professionals partly disagreed (n=6, 66.7%) that *MSD is always associated with a physical injury,* and most (n=7, 77.8%) completely agreed that *psycho-social factors can cause MSD without a physical injury.* Further, the majority of the OSH professionals (n=7, 77.8%) completely agreed that *preventing MSD should include re-organisation of work tasks to maximise variations during working hours,* and all disagreed that *sickness absence is always needed for MSD* (n=9, 100%). No meaningful changes were seen from before to after the training course (Supplementary file 6).

Intervention delivery skills

After the training course, the majority of the OSH professionals (n=6, 75%) answered negatively to lacking the necessary tools and knowledge to deliver the intervention, and five OSH professionals (62.5%) agreed that they knew how to deliver the intervention. Six of eight (75%) OSH professionals agreed or completely agree to feeling comfortable delivering the intervention, and very well or well prepared (Table 1).

Table 1. The perceived delivery skills following the training course (n=8)

Delivery skills post the training course,	**n (%)**
I am lacking the necessary tools and knowledge to deliver the intervention	
Completely agree	0
Agree	0
Neither agree nor disagree	2 (25.0%)
Disagree	6 (75.0%)
Completely disagree	0
I know how to deliver the intervention	
Completely agree	1 (12.5%)
Agree	4 (50.0%)
Neither agree nor disagree	3 (37.5%)
Disagree	0
Completely disagree	0
I feel comfortable delivering the intervention	
Completely agree	1 (12.5%)

Agree	5 (62.5%)
Neither agree nor disagree	2 (25.0%)
Disagree	0
Completely disagree	0
I feel prepared for delivering the intervention	
Very well prepared	1 (12.5%)
Well prepared	5 (62.5%)
Neither well nor poorly prepared	2 (25.0%)

Intervention delivery

Logbooks were completed by the four OSH professionals delivering the PATH@work intervention, with only one of the OSH professionals evaluating all 15 intervention modules. The mean number of workers participating per module ranged from 10 to 18, and the proportion of modules with a manager present ranged from 13% to 100%. Two OSH professionals delivered the recorded modules within the allocated 30-minute per-module time frame. The self-assessed success of delivering the intervention care messages ranged from 6.2 to 9.0, and the overall success from 6.3 to 8.9. No consistent patterns were identified in the delivery of core messages across specific modules, nor in relation to manager presence during module delivery (Table 2 and Supplementary file 7).

Table 2. Descriptive summary of the logbook data

	Occupational health and safety professional			
Logbook data	**1**	**2**	**3**	**4**

Modules evaluated, n (%)	5 (33.3%)	10 (66.7%)	15 (100%)	13 (86.7%)
Mean worker participation per module, n	13	10	18	16
Modules with a manager present, n (%)	5 (100%)	10 (100%)	2 (13.3%)	3 (23.1%)
Modules completed within half an hour	5 (100%)	10 (100%)	11 (73.3%)	9 (69.2%)
Mean score for delivering the core messages per module delivered (0-10)	6.2	9.0	8.6	6.4
Mean score for overall delivery satisfaction per module delivered (0-10)	6.8	8.9	8.9	6.3

Qualitative results

Exploring the training course and intervention delivery

The qualitative data analysis resulted in three overall themes partially aligning with the TFA constructs and relating to 1) the intervention effect, 2) the OSH professionals' role in delivering the intervention, and 3) the need for organisational support.

Theme 1. Positive psychological and social effects of the physical exercises (TFA constructs: affective attitude and perceived effectiveness)

The OSH professionals described that the physical exercises created a positive atmosphere among the workers and a safe space for disclosing work-related pain problems. They had observed that some workers started talking to co-workers more than they normally would. The OSH professionals, therefore, believed the intervention had a positive impact on worker well-being and team collaboration, as it created a new way of being together and shifted the workers' focus away from the work tasks.

"Still, I also find that seeing them, like, from session to session, is like watching them grow a little […] It could be as simple as – sometimes [with the exercises] *they were simply given the chance to talk, and then*

they actually managed to open up about things they'd never spoken to anyone about before, or at least not to each other" (OSH professional 3).

"That's when the social aspect suddenly comes into it. And then you open up while chatting with others… You pair up with a different person [for the exercises] *than you're used to. That might spark those chats about the fact that 'I'm in pain today"* (OSH professional 6).

One OSH professional described the intervention as something positive that could grow and sustain over time: "*The culture and the hurdle are the worst aspects, hands down. We've planted some amazing seeds here; we just need to keep watering them"* (OSH professional 4).

Theme 2. Role uncertainty (TFA constructs: self-efficacy and burden)

Some of the OSH professionals felt uncertain in their new role as intervention deliverers.

"You need teaching experience, and that also means being able to create a positive and inclusive atmosphere […] but I've realised that I'm a bloody good fitness instructor" (OSH professional 8).

When asked to reflect on this uncertainty, many of them thought that in time and with practice, they would feel more comfortable in their role. As one OSH professional said: "*But anyway, it all came together pretty smoothly, and people have taken it in their stride. I think it really depends on the person as well. So, if I did it 10 or 20 times, it starts getting a bit easier to do, of course"* (OSH professional 8).

The OSH professionals felt the preparation time for intervention delivery was considerable and had set aside dedicated time at work or after work to prepare.

"*I think it requires a lot of my time. Both on the day, but also the other days to prepare. I actually spend a lot of time on this [project]"* (OSH professional 3).

Theme 3. The need for organisational support (TFA construct: ethicality)

The majority of the OSH professionals believed that the intervention was relevant for their workplace; however, they emphasized the importance of managerial engagement and support during intervention delivery, and believed managers should make a clear decision on whether participation should be mandatory. As two OSH professionals said:

"I mean, I think everyone has a responsibility, but at the end of the day, it's the senior management's job to say, 'this is something we need to do.' Because we need clear directions, and then we have to make those directions work out there, in the real world" (OSH professional 7).

"It is so important that the management consider the workers as essential to the production. We may reduce illness but overall, it's our well-being and work satisfaction that is important" (OSH professional 2).

Integration of findings (mixed methods)

Themes 2 and 3 were integrated with quantitative data on the OSH professionals' attitudes towards MSD and their perception of their delivery skills, as well as the logbook data. Integration of the data, formed meta-inferences and potential modifications to the training course, relating to content and structure, as well as intervention delivery (Table 3). No links between theme 1 and the quantitative data were established.

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305 **Table 3.** Joint display of the integrated results, meta-inferences, and implications

Themes and meaning units	**Quantitative data**	**Qualitative data**	**Interpretation**	**Meta-inferences and potential modifications to the training course**
Theme 2. Role uncertainty				
Readiness to deliver	75% disagreed that they lacked the necessary tools and knowledge to deliver the intervention 75% felt well prepared for delivering the intervention	*"We needed more background knowledge. More in-depth knowledge to support our teaching"* (OSH professional 2) *"…maybe a kind of manual, telling me what to do next. I need a factsheet. What is next? How do I proceed?"*	**Divergence.** The quantitative data indicated that most of OSH professionals felt prepared to deliver the intervention, had the necessary tools and knew how to deliver the intervention.	The findings illustrate the difference between what to deliver (*intervention content*) and how to deliver (*intervention delivery*). As it was a new role for the OSH professionals, the training course must be modified to:

	75% agreed that they felt comfortable delivering the intervention 63% agreed that they knew how to deliver the intervention, 38% neither/nor	(OSH professional 4) *"I don't believe anyone can do this. Not because I am particularly clever, that's not it. I just mean I need to know how to teach and to be able to make it relevant for you and your co-workers"* (OSH professional 8) *"And if* [the workers] *had high expectations, I'd be left standing there, unable to answer any questions other than what's written*	However, the qualitative data revealed that the OSH professionals were uncertain about delivering the intervention and their own teaching competencies. They identified a need for clearer guidance.	• Strengthen facilitation and delivery skills • Include practice-based training e.g. role play and peer feedback • Include a manual and guidance for intervention delivery

		here. In that case, I don't think they'd have attended modules 5 and 6. It was more about the talking, getting them to start talking [that was difficult]*"* (OSH professional 3)		
Quality of delivery	The number of evaluated modules ranged from 33% to 100% The mean score for delivering the core messages per module ranged from 6.2 to 9	*"Well, we haven't followed the plan to the letter; we've followed the content of the modules, but we've sort of… I've tried to follow up each time… So, sort of trying to make it an ongoing thing. It's a bit like a film, like –*	**Expansion.** The quantitative data showed a variation in module delivery and self-reported ratings. These were explained by the qualitative findings, showing that the OSH	The findings indicate that the intervention content and delivery quality are context sensitive. Co-creation, customisation, and adaptation of intervention materials may enhance engagement.

	The mean score for overall delivery satisfaction per module ranged from 6.3 to 8.9	*we'll be back"* (OSH professional 8). *"When there are several examples* [to explain pain]*, that's when it really starts to make sense. I definitely thought that was really good. As a matter of fact, it fitted in well many times in the other modules, where I brought it up and said, 'Do you remember what we talked about in the first one?' Do you remember the Lego brick? Is the light on,*	professionals had adapted and tailored the delivery to their own setting. Moreover, they found that the quality of the intervention delivery improved with visuals and examples.	Training course modifications must include: • Flexibility in intervention delivery methods • Visual aids, examples, and pictures in the training course and intervention materials

		or is it off?" (OSH professional 2) *"We found that* [the workers] *did much better when they were handed a Post-it note than when they had to talk too much in the group or had to go and write on the flip chart"* (OSH professional 4)		
Uptake and practical delivery	The mean worker participation per module ranged from 10-18	*"Instead of half-hour modules, use one hour for the theory during a toolbox meeting, and then do the exercises. Then follow up on*	**Expansion.** The quantitative data indicated variation in worker participation rates and module delivery time.	We found that the intervention was operationally feasible, but required modifications in format and delivery frequency to fit workplace settings.

	The number of modules completed within half an hour ranged from 69% to 100%	*the theory at the next meeting. The exercises could also be started with a video"* (OSH professional 8) *"The theory works better in larger modules, and with daily practice. We could start with a workshop on the biopsychosocial approach and then follow up later or during the training. You can also do the training via a video link" (*OSH professional 3)	The qualitative data revealed that the intervention could be delivered in blocks containing several modules, using digital tools to improve delivery and reach.	Training course modifications must include: • A mixture of in-person and digital delivery formats • Structuring the intervention modules into blocks • Allow for variations in delivery across different contexts
Theme 3. The need for organisational support				

Shared understanding of MSD prevention	100% agreed that physical, psychological, and social factors should be included in MSD prevention 100% agreed that workplace MSD prevention is affected by the understanding of MSD 100% disagreed that sickness absence is always needed for MSD	*"I notice an issue: not everybody can do this. Because you need experience and knowledge. And you need in-depth knowledge to be able to teach. So, I think it will be a matter of resources as more people need the skills and more time is needed to be able to teach across sites"* (OSH professional 5)	**Expansion.** The quantitative data indicated that the OSH professionals agreed upon the essential of a shared workplace understanding of MSD. However, the qualitative data illustrated challenges with the dissemination of this knowledge to the whole organisation.	We found that the intervention was consistent with individuals' knowledge and perceptions. However, creating a common understanding across a workplace may be challenging. Training course modifications must include: • Engagement at all organisational levels • Digital materials to create a common understanding across the organisation

Active and adaptive work practices	78% agreed that there is not one correct work position or lifting technique to prevent MSD 100% agreed that preventing MSD should include re-organisation of work tasks to maximise variations during the working hours 100% agreed that physical activity and exercise may be beneficial, even for	*"I think we need to continue. It works well with the exercises; we really need to continue this"* (OSH professional 2) *"But I also subscribe to the idea of having a group that's been, like, taught. It kind of spreads like ripples in a pond, if they were able to act as ambassadors. Then I didn't have to drag* [the workers] *out. More people can nudge each other"* (OSH professional 7)	**Complementary.** The quantitative show positive attitudes towards adaptive work practices and the introduction of physical exercises. The qualitative data supported this, revealing that intervention sustainability requires ongoing reinforcement with a potential for using local ambassadors and peer-driven activities.	To support intervention sustainability, the training course modifications may include: • Introduction of peer support and local ambassadors • Integration of intervention with existing work tasks

	workers with high levels of MSD	*"We will continue with the exercises 100%"* (OSH professional 3)		
Shared responsibilities and social support across organisational levels	89% agreed that preventing MSD at the workplace involves the individual worker, the team, the manager and upper management 100% agreed that dialogue and support from co-workers and managers can prevent MSD	*"The most important part is probably to engage the workers as much as possible, maybe we could have a go-to person. A person people could ask: 'I have pain here; what do you think I should do?"* (OSH professional 1) *"Everybody needs to be prepared to help each*	**Complementary.** The quantitative data suggested shared responsibilities for preventing MSD. The qualitative data emphasised dialogue, openness, and peer support as important activities for preventing MSD.	MSD was understood by the OSH professionals as collective and relational, and strengthening the psycho-social work environment may help prevent MSD. Training course modifications may include: • Group reflections and peer support to improve the OSH professionals' skills to

		other, and talk to each other. I think talking openly will help. I don't necessarily think an exercise will help, but more that we can talk and support each other. This will have a huge effect" (OSH professional 2)		facilitate dialogue and communication • Opening the training course to dedicated workers to improve organisational knowledge and skills
Organisational engagement	Modules with a manager present ranged from 13.3% to 100%	*"But* [the manager] *has been down to observe. But higher up in the organisation, they actually knew less about the project* (OSH professional 1)	**Converge.** The quantitative and the qualitative data indicated inconsistent management involvement.	We found that the prevention of workplace MSD required engagement at all organisational levels. Training course modifications may include:

				• Early and explicit engagement of managers • Defining clear roles for the managers in the intervention • Integrating intervention into organisational priorities • Management-specific training

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Discussion

We conducted a mixed-method feasibility study to evaluate the newly developed training course targeting OSH professionals and their intervention delivery. Overall, we found that the OHS professionals had knowledge and perceptions aligning with a biopsychosocial understanding of MSD and the intervention core messages, already before the training course. However, the training course did not sufficiently equip the OSH professionals with the skills and competencies needed to confidently deliver the intervention components and facilitate workplace changes. Thus, our findings illustrate the clear distinction between intervention content and delivery, and the different levels of competencies required for effective knowledge transfer. Finally, we identified a clear need for organisational support from the manager for OSH professionals to be successful in their role as intervention deliverers.

The training course was designed as a one-day program. The length of the program was informed by input from workplace stakeholders, who were mindful of the resources needed to participate in the program. The shorter duration appears to have been insufficient, and in comparison, the clinical GLA:D® program, provides a two-day course for healthcare professionals to deliver a similar evidence-based intervention for patients with hip, knee, and back pain (27, 28). However, studies suggest that course content and structure are more influential than duration alone (10, 18). In the planning of the training course, we prioritised the delivery of mandatory intervention core messages combined with providing practical tools to support the participatory processes, such as dialogue cards, open-ended questioning techniques, and structured group discussions. However, the OSH professionals had high levels of knowledge aligning with the core messages already before the training course, reducing the need for training in this aspect. Furthermore, they reported insufficient competence in delivering the intervention, suggesting that the anticipated change mechanisms and outcomes (e.g. new ways of working or talking more openly about MSD) were not fully activated. Participatory interventions require facilitation of worker engagement in the workplace change process (16), which again requires appropriate training and a specific skill set (18, 29, 30). This suggests that

restructuring the training course content to focus more on facilitation of change processes may be more beneficial than simply increasing its length. Furthermore, follow-up online sessions and implementer networks may facilitate knowledge exchange, experiential learning and ongoing competence development among OSH professionals during and following the training course (18).

The OHS professionals had different professional backgrounds and held different positions, which likely impacted their ability to deliver the intervention (9). Reduced pedagogical quality and dilution of content are well-known challenges of the train-the-trainer approach as the intervention is disseminated through an organisation (8). Yet, local workplace ambassadors may still be more effective in delivering psycho-social interventions compared to external educators, as local ambassadors possess greater credibility, are more likely to employ active learning strategies and can tailor these to context-specific, practical workplace needs (12).

We assessed the OSH professionals' knowledge, skills, and attitudes towards the training course and delivery. To further support capacity-building of the OSH professionals, standardised tools like the Implementation Support Competencies Assessment tool may be used to measure the required pre-training course competencies and training effects (31), and future studies should incorporate more distal outcome measures to evaluate long-term organisational learning and behavioural changes to capture the transfer of knowledge beyond the training course (18).

Importantly, the OSH professionals expressed a need for greater organisational support. This key feature has been consistently recognised in other work (16, 32). In accordance with the CoWork model, active involvement of all organisational levels is essential to foster collective ownership (33). Organisational involvement can support the OSH professionals to have the necessary time, resources, and managerial

backing to deliver the workplace interventions. This, in turn, strengthens collective ownership and increases the likelihood that interventions are implemented and sustained (34).

When delivering the intervention, the OSH professionals adapted some degree of flexibility. This approach was not taught during the training program but aligns well with the Medical Research Council framework for developing and evaluating complex interventions, emphasising ongoing adaptation to the context (35). As a consequence, we observed variation in intervention delivery across workplaces; some OSH professionals delivered the intervention modules sequentially, whilst others delivered them in blocks. In implementation research, fidelity is commonly assessed to ensure accurate replication of the intervention and to attribute outcomes to the intervention itself (36). However, in workplace settings characterised by continuously evolving contextual factors, strict adherence to predefined procedures may be neither feasible nor desirable (37, 38).

Methodological strengths and limitations

A key strength of this study is the application of a mixed methods approach across the design, data collection, and analysis phases (39). The collection of several different data sets and their integration enabled triangulation of data and a more comprehensive and nuanced evaluation of the training course and intervention delivery. Several limitations should be acknowledged. Firstly, the study included a small sample size and lacked a control group, a typical features of exploratory feasibility studies, which limit the generalisability of the findings (40). However, it may be argued whether generalisability is reachable when conducting complex interventions in constantly changing workplace contexts (41). Secondly, OSH professionals were appointed to the study by their managers, which may have influenced their motivation to participate and their engagement with the intervention over time. Finally, we used non-validated questionnaires and asymmetrical response scales, which potentially limit the validity of the findings.

Conclusion

The OHS professionals already possessed knowledge and perceptions consistent with a biopsychosocial understanding of MSDs and the core messages of the intervention before the training. Despite their positive self-evaluation in the questionnaires of intervention delivery, the qualitative data elucidated that the training itself did not adequately develop the skills and competencies required for them to confidently implement the intervention components or drive workplace changes. In revising the training course content, more emphasis should be put on technical facilitation, relational and organisational skills. Addressing these areas is likely to strengthen the train-the-trainer delivery strategy and improve the feasibility of delivering the intervention.

Supplementary file 1

Description of the 15 PATH@work intervention modules.

Module	Musculoskeletal health literacy	Participatory ergonomics	Core messages	Physical exercises
1	MSD is not always due to a physical injury	Structured plenum dialogue, *think about a situation where you experienced MSD – what characterised the situation?*	MSD is an individual experience associated with potential or actual damage MSD is most often not associated with a physical injury	General movements for the whole body
2	MRI scans do not show MSD	Structured plenum dialogue, *what are your reflections on the core messages?*	MRI scans do not show MSD and do not direct MSD management Osteoarthritis and disc prolapse are normal signs of ageing	General movements for the whole body
3	MSD is affected by experiences and thoughts	Structured plenum dialogue, *think about a situation where you experienced MSD – what*	The brain may increase or decrease the perception of MSD	Exercises focusing on mobility and stretching

		were your thoughts and how did you react?	Thoughts and experiences affect behaviour and MSD	
4	MSD should be seen from the biopsychosocial model	Plenum brainstorm on factors related to the bio-psycho-social model, followed by dialogue in pairs: *What factors affect MSD for you?*	Perception of MSD is individual MSD is multi-factorial	Audio file with mindfulness
5	MSD mapping with sticky notes	Plenum mapping of MSD	MSD is common MSD is prevalent at the workplace	Exercises focusing on the body part with the highest rate of MSD
6	Rest, medicine, massage and operations are not effective long-term treatments for MSD	Own reflection on the effects of exercises, *did you find a particular exercise helpful? Rate on a scale from 0-10 before and after doing exercises.*	Treatment of MSD is individual Movements and pacing of activities are recommended	Three exercises for the back, shoulder and knees.
7	There is no right or wrong way to do your work tasks Reducing risk factors is the only way to manage MSD	Plenum dialogue, *was any of these statements surprising? What may be the consequences for us?*	Perception of physically demanding work tasks is individual There is no ergonomic right or wrong way to	General movements for the whole body

			carry out work tasks to prevent MSD	
8	Activity and movement are recommended	Reflections and dialogue in pairs, *how can we introduce movements and exercises during work hours?*	The body is designed to move Activity and movements may decrease MSD	Cardio-vascular exercises such as running on the spot, fast circling of the arms, squats with high pace
9	Focusing on positive things may reduce MSD	Reflections and dialogue in pairs, *during what situations you feel less MSD?*	Focused relaxation may reduce MSD	Audio file with mindfulness
10	Focus on function or activities instead of MSD	Individual sticky notes, *what activities or work tasks is challenging due to MSD?*	Pacing of activities and different organisation of work tasks may reduce MSD Recurrent MSD is normal	Exercises focusing on mobility and stretching
11	The CoWork model	Plenum dialogue on possible solutions for MSD at each CoWork level, *what possibilities do we have?* *How can we work together across the levels?*	Challenges and solutions may exist at each CoWork level Challenges should be solved jointly at the different levels	3-5 workers select an exercise for the other workers

			It is everybody's responsibility to manage MSD at the workplace	
12	Balancing demands and resources	Plenum dialogue on work tasks that may be demanding, and identification of available resources, *how can we prevent MSD at our workplace? How can we work together to prevent MSD?*	Challenges and solutions may involve the individual worker, the group, the manager or the whole organisation Increasing resources may be possible through individual initiatives and in collaboration with co-workers and managers	3-5 workers select an exercise for the other workers
13	Physical exercises reduce MSD	Plenum dialogue on how to implement physical exercises at work, *how can we implement exercises during work hours?*	Regular physical exercise at work may reduce MSD and increase well-being at work	Strengthen exercises with exercise bands
14	Open dialogue on MSD at work	Structured dialogue with dialogue cards in small groups, e.g. *how do we manage MSD? What are the possibilities and barriers?*	Open dialogue about challenges and solutions is recommended	Strengthen exercises with exercise bands

			Collaboration is only possible through open dialogue Solutions may be day-to-day or more long-term	
15	Workplace action plan	Plenum identification of challenges and solutions through workplace action plans	Collaboration of workers and managers is needed to identify solutions	General movements for the whole body

Abbreviations: MSD = Musculoskeletal Disorders.

Supplementary file 2

Baseline questionnaire for the occupational safety and health professionals assessing their attitudes towards musculoskeletal disorders.

Knowledge and attitudes on Musculoskeletal Disorders					
MSD is always associated with a physical injury					
Completely agree	Partly agree	Slightly agree	Slightly disagree	Partly disagree	Completely disagree
MSD is a sign of a physical strain e.g. related to a work accident					
Completely agree	Partly agree	Slightly agree	Slightly disagree	Partly disagree	Completely disagree
MSD is affected by our mind, experiences and surroundings e.g. thoughts, feelings and support					
Completely agree	Partly agree	Slightly agree	Slightly disagree	Partly disagree	Completely disagree
Psycho-social factors can cause MSD without physical injury					
Completely agree	Partly agree	Slightly agree	Slightly disagree	Partly disagree	Completely disagree
Preventing Musculoskeletal Disorders at the workplace					

Sickness absences is always needed for MSD					
Completely agree	Partly agree	Slightly agree	Slightly disagree	Partly disagree	Completely disagree
There is not one correct work position and lifting technique to prevent MSD					
Completely agree	Partly agree	Slightly agree	Slightly disagree	Partly disagree	Completely disagree
Preventing MSD should include re-organising work tasks to maxmise variations during working hours					
Completely agree	Partly agree	Slightly agree	Slightly disagree	Partly disagree	Completely disagree
Physical activity and exercise may be beneficial, even for workers with high levels of MSD					
Completely agree	Partly agree	Slightly agree	Slightly disagree	Partly disagree	Completely disagree
To prevent MSD physical, psychological and social factors should be assessed					
Completely agree	Partly agree	Slightly agree	Slightly disagree	Partly disagree	Completely disagree
Understanding MSD will affect prevention of MSD at the work place					
Completely agree	Partly agree	Slightly agree	Slightly disagree	Partly disagree	Completely disagree

Preventing MSD at the workplace involves the individual worker, the team, the manager and upper management					
Completely agree	Partly agree	Slightly agree	Slightly disagree	Partly disagree	Completely disagree
Dialogue and support from co-workers and managers can prevent MSD					
Completely agree	Partly agree	Slightly agree	Slightly disagree	Partly disagree	Completely disagree

MSD =musculoskeletal disorders

401 **Supplementary file 3**

402 Post training course questionnaire for the for the occupational safety and health professionals

Delivery skills post the training course				
I am lacking the necessary tools and knowledge to deliver the intervention				
Completely agree	Agree	Neither agree nor disagree	Disagree	Completely disagree
I know how to deliver the intervention				
Completely agree	Agree	Neither agree nor disagree	Disagree	Completely disagree
I feel comfortable delivering the intervention				
Completely agree	Agree	Neither agree nor disagree	Disagree	Completely disagree
I feel prepared for delivering the intervention				
Very well prepared	Well prepared	Neither well nor poorly prepared		

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405 **Supplementary file 4**

406 Logbook for intervention delivery

Intervention delivery assessment	Response options
Which module are you evaluating?	Module 1-15
How many workers participate in the module?	Number of participants
Was a manager present during the module?	Yes/no
Did you deliver the module within half hour?	Yes/no
To what extent were the core messages successfully delivered?	0-10 (0 =not successful, 10= extremely successful)
How satisfied were you with the overall delivery of the module?	0-10 (0 =not satisfied at all, 10= extremely satisfied)

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409 # Supplementary file 5

410 Interview guide for the occupational safety and health professionals.

Theme	Interview question	Prompts
Introduction	What's your name?	
Delivery	How did you find delivering the intervention? What did you find positive or negative? And why?	For example, the content or materials Can you describe an example?
The training course	How did you find the training course? What did you find positive or negative? And why?	Did you gain any knowledge and skills to deliver the intervention? Was the length and format adequate? Were the materials easy to understand?

TFA - Affective attitude *How an individual feels about the intervention*	How did you find the intervention? What did you find positive or negative? And why?	Does the intervention fit your work tasks and planning?
TFA - Burden *The amount of effort required to participate in the intervention*	What did it require of you? Both the training course and delivery	E.g. other work tasks, preparation, mental burden
TFA - Ethicality *The extent to which the intervention has good fit with an individual's value system*	Did you find the intervention relevant for your workplace? Who is responsible for preventing MSD at the workplace?	Did anything unexpected happen? Did the intervention fit your beliefs about preventing MSD?
TFA - Perceived effectiveness *The extent to which the intervention is perceived to have achieved its objective*	What was the effect of the intervention? Is there anything you want to continue?	Any new knowledge? Do you talk differently about MSD? Can you describe an example?

TFA- Intervention coherence *The extent to which the participant understands how the intervention works*	How do you understand the intervention components? Knowledge on MSD Physical exercises Participatory ergonomics?	How do you think the intervention can help to prevent MSD? Is anything different now?
TFA - Self -efficacy *A participant's confidence that they can perform behaviour(s) required to participate in the intervention*	Do you think, you can continue with the intervention? Any particular components?	Why/why not? Who needs to be involved?
TFA - Opportunity costs *The benefits, profits or values that would have to be given up to engage with the intervention*	Was there anything you needed to change due to the intervention? Anything you needed to cancel or postpone due to the intervention?	E.g. work tasks, meetings, other activities

Barriers and opportunities	What were the barriers and opportunities for delivering the intervention? What did you do to overcome the barriers?	E.g. information, communication, time, workers, managers Did you have any support at the workplace?
Motivation	What was your motivation for participating in the intervention?	Why/why not?
Continuation	What are our main learning outcomes? Will you continue?	What was positive or negative? Why/why not Give examples
Digital materials	Did you use the website to access the digital materials?	What worked well/less well?
Finishing	Is there anything you want to add?	

411 *MSD =musculoskeletal disorders; TFA=theoretical framework of acceptability*

412

413 # Supplementary file 6

414 Descriptive statistics for baseline and follow-up data on the occupational safety and health professional's
415 attitude on musculoskeletal disorders and prevention of musculoskeletal disorders at the workplace.

Variable		
Knowledge on MSD, n(%)	**Baseline (n=9)**	**Follow-up (n=8)**
MSD is always associated with a physical injury		
Completely agree	1(11.1%)	0
Partly agree	0	1(12.5%)
Slightly agree	0	0
Slightly disagree	0	0
Partly disagree	6(66.7%)	4(50%)
Completely disagree	2(22.2%)	3(37.5%)
MSD is a sign of a physical strain e.g. related to a work accident	1(11.1%)	0
Completely agree	1(11.1%)	3(37.5%)
Partly agree	0	0
Slightly agree	2(22.2%)	0
Slightly disagree	5(55.6%%)	3(37.5%)
Partly disagree	0	2(25%)
Completely disagree		

MSD is affected by our mind, experiences and surroundings e.g. thoughts, feelings and support	8 (88.9%)	6(75%)
Completely agree	0	2(25%)
Partly agree	0	0
Slightly agree	0	0
Slightly disagree	1(11.1%)	0
Partly disagree	0	0
Completely disagree		
Psycho-social factors can contribute to MSD without physical injury		
Completely agree	7(77.8%)	7(87.5%)
Partly agree	1(11.1%)	1(11.1%)
Slightly agree	0	0
Slightly disagree	1(11.1%)	0
Partly disagree	0	0
Completely disagree	0	0
Preventing MSD at the workplace, n(%)		
Sickness absences is always needed for MSD		
Completely agree	0	0
Partly agree	0	0
Slightly agree	0	0

Slightly disagree	1(11.1%)	0
Partly disagree	0	2(25%)
Completely disagree	8(88.9%)	6(75%)
There is not one correct work position and lifting technique to prevent MSD		
Completely agree	4(44.4%)	5(62.5%
Partly agree	3(33.3%)	2(25%)
Slightly agree	0	1(12.5%
Slightly disagree	1(11.1%	0
Partly disagree	1(11.1%)	0
Completely disagree	0	0
Preventing MSD should include re-organisation of work tasks to maximise variations during working hours		
Completely agree	7(77.8%)	5(62.5%)
Partly agree	1(11.1%)	3(37.5%)
Slightly agree	1(11.1%)	0
Slightly disagree	0	0
Partly disagree	0	0
Completely disagree	0	0
Physical activity and exercise may be beneficial, even for workers with high levels of MSD		

Completely agree	8(88.9%)	8(100%)
Partly agree	1(11.1%)	0
Slightly agree	0	0
Slightly disagree	0	0
Partly disagree	0	0
Completely disagree	0	0
To prevent MSD physical, psychological and social factors should be assessed		
Completely agree	9(100%)	8(100%)
Partly agree	0	0
Slightly agree	0	0
Slightly disagree	0	0
Partly disagree	0	0
Completely disagree	0	0
Understanding MSD will affect prevention of MSD at the work place		
Completely agree	9(100%)	8(100%)
Partly agree	0	0
Slightly agree	0	0
Slightly disagree	0	0
Partly disagree	0	0
Completely disagree	0	0

Preventing MSD at the workplace involves the individual worker, the team, the manager and upper management		
Completely agree	8(88.9%)	7(87.5%)
Partly agree	0	1(12.5%)
Slightly agree	0	0
Slightly disagree	0	0
Partly disagree	1(11.1%)	0
Completely disagree	0	0
Dialogue and support from co-workers and managers can prevent MSD *		
Completely agree		
Partly agree	6(100%)	5(62.5%)
Slightly agree	0	3(37.5%)
Slightly disagree	0	0
Partly disagree	0	0
Completely disagree	0	0
	0	0

**baseline (n=6)*

MSD =musculoskeletal disorders

Supplementary file 7

Logbook data for the occupational safety and health professionals.

	OSH professional 1					OSH professional 2					OSH professional 3					OSH professional 4				
	N	Manager present	<0,5 hour	Message Delivery (0-10)	Overall rating (0-10)	N	Manager present	<0,5 hour	Message delivery (0-10)	Overall rating (0-10)	N	Manager present	<0,5 hour	Message delivery (0-10)	Overall rating (0-10)	N	Manager present	<0,5 hour	Message Delivery (0-10)	Overall rating (0-10)
Module 1	12	Yes	Yes	10	10	7	Yes	Yes	10	9	18	No	Yes	9	10	-	-	-	-	-
Module 2	14	Yes	Yes	8	4	7	Yes	Yes	10	10	18	No	-	9	10	17	No	Yes	8	8
Module 3	12	Yes	Yes	-	8	7	Yes	Yes	8	8	19	Yes	Yes	8	8	13	No	Yes	6	7
Module 4	12	Yes	Yes	3	2	7	Yes	Yes	9	9	18	No	Yes	10	10	13	No	-	6	7
Module 5	14	Yes	Yes	10	10	-	-	-	-	-	17	No	Yes	9	8	17	No	Yes	6	7

Module 6	-	-	-	-	-	-	-	-	-	-	18	No	No	10	10	17	No	Yes	5	6
Module 7	-	-	-	-	-	-	-	-	-	-	19	Yes	Yes	7	9	17	No	-	6	6
Module 8	-	-	-	-	-	12	Yes	Yes	9	9	18	No	Yes	9	9	-	-	-	-	-
Module 9	-	-	-	-	-	12	Yes	Yes	9	9	18	No	Yes	9	9	17	No	Yes	8	
Module 10	-	-	-	-	-	12	Yes	Yes	8	8	17	No	Yes	8	8	17	No	No	7	7
Module 11	-	-	-	-	-	12	Yes	Yes	8	8	18	No	Yes	9	9	17	Yes	Yes	7	7
Module 12	-	-	-	-	-	11	Yes	Yes	9	9	17	No	No	6	8	16	No	Yes	6	7
Module 13	-	-	-	-	-	11	Yes	Yes	10	10	18	No	Yes	9	9	16	Yes	Yes	5	6
Module 14	-	-	-	-	-	-	-	-	-	-	15	No	No	8	8	16	No	Yes	6	6
Module 15	-	-	-	-	-	-	-	-	-	-	17	No	Yes	9	9	13	Yes	-	7	8

421 *OSH=occupational safety and health professional; N=number of workers participating; <0,5=module delivered within half an hour, -= missing data*

List of abbreviations

MSD: Musculoskeletal Disorders

OSH: Occupational Safety and Health

GLA:D®: Good Life with OsteoArthritis in Denmark

TFA: Theoretical Framework of Acceptability

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. The Committees on Health Research Ethics for the Capital Region of Denmark assessed the study (Ref number: F-24011807)and concluded that ethical approval was not required as the planned evaluation of the study did not fall under the definition of the laws defined in Committee Act § 2 and § 1 (42). Participation in the study was voluntary, and written informed consent was obtained from all participants before the study began.

Consent for publication

Not applicable.

Availability of data materials

The interview datasets analysed during the current study are not publicly available due to concerns regarding participant anonymity. Other datasets generated and/or analysed during the study are available from the corresponding author on reasonable request.

Competing interests

AK is a co-developer of GLA:D®. A non-for-profit initiative hosted at University of Southern Denmark aimed at implementing evidence-based patient education and exercise therapy for hip, knee and back pain in clinical practice.

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Authors' contributions

MS designed and developed the training course, recruited the workplaces, carried out the interviews, analysed the data and wrote the first manuscript draft.

AK developed the training course and contributed to overall study design and evaluation.

KS developed the research idea and ensured funding for the study.

RSL, SBTJ and SVS developed the training course and contributed to data analysis and evaluation.

MJS developed the training course, contributed to data analysis and evaluation, and supervised the study.

All authors read and approve the final manuscript.

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References

1. World Health Organization. Musculoskeletal Health 2022 [Available from: https://www.who.int/news-room/fact-sheets/detail/musculoskeletal-conditions.
2. de Kok J, Vroonhof P, Snijders J, Roullis G, Clarke M, Peereboom K, et al. Work-related musculoskeletal disorders: prevalence, costs and demographics in the EU. Luxembourg: European Agency for Safety and Health at Work - EU-OSHA; 2019.
3. Liu M, Rong J, An X, Li Y, Min Y, Yuan G, et al. Global, regional, and national burden of musculoskeletal disorders, 1990-2021: an analysis of the global burden of disease study 2021 and forecast to 2035. Front Public Health. 2025;13:1562701.
4. Qiu K, Wang C, Mo X, Yang G, Huang L, Wu Y, et al. The global macroeconomic burden of musculoskeletal disorders. Int J Surg. 2025.
5. Jacobsen SS, Lindberg L, Andersen LL, A. H. Vidensopsamling om effektiv forebyggelse af MSB og fysisk nedslidning. Copenhagen; 2024.
6. World Health Organization. Healthy workplaces: a model for action 2010 [Available from: https://www.who.int/publications/i/item/9789241599313.
7. Svendsen MJ, Schmidt KG, Holtermann A, Rasmussen CDN. Expert panel survey among occupational health and safety professionals in Denmark for prevention and handling of musculoskeletal disorders at workplaces. Safety Sci. 2020;131:104932.
8. Harper M, Gore J, Harris J. A new conceptual framework for understanding and implementing train-the-trainer professional development on a large scale. Prof Dev Educ. 2024.
9. Wisshak S, Hochholdinger S. Trainers' knowledge and skills from the perspective of trainers, trainees and human resource development practitioners. Int J Train Res. 2018;16(3):218-31.
10. Pearce J, Mann MK, Jones C, van Buschbach S, Olff M, Bisson JI. The most effective way of delivering a Train-the-Trainers program: A systematic review. J Contin Educ Health Prof. 2012;32(3):215-26.

11. Nexø MA, Kingod NR, Eshøj SH, Kjærulff EM, Nørgaard O, Andersen TH. The impact of train-the-trainer programs on the continued professional development of nurses: a systematic review. BMC Med Educ. 2024;24(1):30.

12. Callaway CA, Varghese JM, Agnew ER, Sarfan LD, Harvey AG. An Examination of Training Quality and Provider Outcomes Across Two Generations of Train-the-Trainer. Administration and Policy in Mental Health and Mental Health Services Research. 2025;52(5):966-82.

13. O'Reilly H, Van Eerd D. Including the ergonomist's voice in integrating MSD prevention and psychological health and safety: Challenges, tools, and considerations. Appl Ergon. 2025;122:104405.

14. Krishnanmoorthy G, Rampal S, Karuthan SR, Baharudin F, Krishna R. Effectiveness of Participatory Ergonomic Interventions on Work-Related Musculoskeletal Disorders, Sick Absenteeism, and Work Performance Among Nurses: Systematic Review. JMIR Hum Factors. 2025;12:e68522.

15. Rossen CB, Jannsen BE, Stochkendahl MJ, Christiansen DH, Hubeishy MH. The Implementation of the Toolbox “Talk About Pain—Take Action Together” to Improve Musculoskeletal Pain Management in the Workplace. Journal of Occupational Rehabilitation. 2026.

16. Hansen AF, Hasle P, Caroly S, Reinhold K, Järvis M, Herrig AO, et al. Participatory ergonomics: What works for whom and why? A realist review. Ergonomics. 2024;67(1):13-33.

17. Schønheyder M, Stilling MN, Rasmussen CDN, Kongsted A, Søgaard K, Holtermann A, et al. Development of the multicomponent PATH@work intervention for musculoskeletal disorders among blue-collar workers Integrating evidence-based clinical care and workplace interventions. . PREPRINT (Version 1) available at Research Square 2026.

18. Wisshak S, Schäfer P, van Waveren L. Train-The-Trainer: A Generic Offer-And-Use Model for the Development of Trainers. Int J Train Dev. 2025;29(4):449-61.

19. Cresswell J, Clark V. Designing and Conducting Mixed Methods Research. 3rd ed. London: Sage; 2018.

20. Skamagki G, King A, Carpenter C, Wåhlin C. The concept of integration in mixed methods research: a step-by-step guide using an example study in physiotherapy. Physiother Theory Pract. 2024;40(2):197-204.
21. Ris I, Schröder K, Kongsted A, Abbott A, Nilsen P, Hartvigsen J, et al. Adapting the determinants of implementation behavior questionnaire to evaluate implementation of a structured low back pain programme using mixed-methods. Health Sci Rep. 2021;4(2):e266.
22. Sekhon M, Cartwright M, Francis JJ. Development of a theory-informed questionnaire to assess the acceptability of healthcare interventions. BMC Health Serv Res. 2022;22(1):279.
23. Sekhon M, Cartwright M, Francis JJ. Acceptability of healthcare interventions: an overview of reviews and development of a theoretical framework. BMC Health Serv Res. 2017;17(1):88.
24. Ritchie J, Lewis J, Nicholls C, Ormston R. Qualitative Research Practice. 2nd ed. London: Sage; 2014.
25. Gale NK, Heath G, Cameron E, Rashid S, Redwood S. Using the framework method for the analysis of qualitative data in multi-disciplinary health research. BMC Med Res Methodol. 2013;13:117.
26. Younas A, Fàbregues S, Munce S, Creswell JW. Framework for types of metainferences in mixed methods research. BMC Med Res Methodol. 2025;25(1):18.
27. Skou ST, Roos EM. Good Life with osteoArthritis in Denmark (GLA:D™): evidence-based education and supervised neuromuscular exercise delivered by certified physiotherapists nationwide. BMC musculoskeletal disorders. 2017;18(1):72.
28. Kjaer P, Kongsted A, Ris I, Abbott A, Rasmussen CDN, Roos EM, et al. GLA:D(®) Back group-based patient education integrated with exercises to support self-management of back pain - development, theories and scientific evidence. BMC Musculoskelet Disord. 2018;19(1):418.
29. Stochkendahl MJ, HAsle P, Hansen ABG, Heiberg BD, Öhler W, Herrig AO, et al. Worker participation in the prevention of musculoskeletal risks at work. Luxembourg: Publications Office of the European Union; 2022.

30. Albers B, Metz A, Burke K, Bührmann L, Bartley L, Thoma P, et al. Implementation Support Skills: Findings From a Systematic Integrative Review. Research on Social Work Practice. 2020;31.
31. Jensen TM, Metz AJ, Albers B. Development and psychometric evaluation of the Implementation Support Competencies Assessment. Implement Sci. 2024;19(1):58.
32. Nielsen K, Sorensen G, El-Salanti N, Munch-Hansen M. Designing, Implementing, and Evaluating Sustainable Interventions in Organizations: The How-To of Improving Worker Health and Well-being: Oxford University Press; 2025. Available from: https://doi.org/10.1093/9780197791622.001.0001.
33. Holtermann A, Sørensen OH, Jacobsen SS, Lindberg L, Andersen LL. Beyond risk reduction of work-related musculoskeletal disorders: The CoWork musculoskeletal health model. Scand J Work Environ Health. 2025.
34. Nielsen K, Christensen M. Positive Participatory Organizational Interventions: A Multilevel Approach for Creating Healthy Workplaces. Front Psychol. 2021;12.
35. Skivington K, Matthews L, Simpson SA, Craig P, Baird J, Blazeby JM, et al. A new framework for developing and evaluating complex interventions: update of Medical Research Council guidance. BMJ. 2021;374:n2061.
36. Proctor E, Silmere H, Raghavan R, Hovmand P, Aarons G, Bunger A, et al. Outcomes for implementation research: conceptual distinctions, measurement challenges, and research agenda. Adm Policy Ment Health. 2011;38(2):65-76.
37. Nielsen K, Miraglia M. What works for whom in which circumstances? On the need to move beyond the 'what works?' question in organizational intervention research. Human Relations. 2017;70(1):40-62.
38. Nielsen K, Sorensen G, El-Salanti N, Munch-Hansen M. Introduction: Designing, implementing, and evaluating sustainable interventions in organizations: The how-to of improving worker health and well-being. 2025 [cited 3/17/2026]. In: Designing, Implementing, and Evaluating Sustainable

Interventions in Organizations: The How-To of Improving Worker Health and Well-being [Internet]. Oxford University Press, [cited 3/17/2026]; [0]. Available from: https://doi.org/10.1093/9780197791622.003.0001.

39. Skamagki G, King A, Duncan M, Wåhlin C. A systematic review on workplace interventions to manage chronic musculoskeletal conditions. Physiother Res Int. 2018;23(4):e1738.

40. Bowen DJ, Kreuter M, Spring B, Cofta-Woerpel L, Linnan L, Weiner D, et al. How we design feasibility studies. Am J Prev Med. 2009;36(5):452-7.

41. Dalgaard VL, Kirkegaard T, Wåhlin-Jacobsen CD, Aust B, Jaspers S, Jønsson TF, et al. Can an organizationally anchored, multilevel intervention improve perceived stress and psychosocial factors in the workplace? A pre-post study assessing effectiveness and implementation. BMC Public Health. 2025;25(1):384.

42. Indenrigs- og Sundhedsministeriet. Bekendtgørelse af lov om videnskabsetisk behandling af sundhedsvidenskabelige forskningsprojekter og sundhedsdatavidenskabelige forskningsprojekter 2023 [15-06-2026]. Available from: https://www.retsinformation.dk/eli/lta/2024/1268.