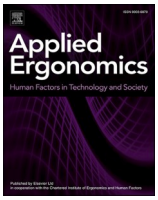
Applied Ergonomics 112 (2023) 104074

Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo



Does occupational health surveillance lead to risk reduction for workers exposed to hand-intensive work?

Kristina Eliasson [a,b,*], Charlotte Lewis [c], Therese Hellman [a,b], Gunilla Dahlgren [c], Magnus Svartengren [a,b], Teresia Nyman [a,b]

[a] Department of Medical Sciences, Occupational and Environmental Medicine, Uppsala University, Uppsala, Sweden
[b] Department of Occupational and Environmental Medicine, Uppsala University Hospital, Uppsala, Sweden
[c] Department of Public Health and Clinical Medicine, Section of Sustainable Health, Umeå University, 901 87, Umeå, Sweden

ARTICLE INFO

Keywords:
Musculoskeletal disorders
Risk assessment
Risk control

ABSTRACT

This mixed method study aimed to describe what risk-reducing actions were proposed by ergonomists after the execution of a guided process for occupational health surveillance for workers exposed to hand-intensive work in ten companies. Another aim was to describe the exposed workers' proposals for risk-reducing actions, including their perceptions of potential changes in the self-assessed exposure levels and work-related pain. Several actions, targeting organizational, technical, and/or individual measures were proposed. Proposals from the ergonomists more often targeted the personal measures, whereas the workers' proposals targeted technology or organizational changes. Six companies implemented at least one of the action proposals. These action proposals were not related to evaluation metrics, nor were they evaluated. This study indicates that both ergonomists and companies need guidance on how to improve to work in a participatory process for the implementation and evaluation of risk-reducing actions, e.g., by how to better include workers' experiences.

1. Background

Work-related neck and upper limb musculoskeletal disorders represent a substantial proportion of occupational ill-health and are associated with long absences from work and high societal costs (Barr et al., 2004; Bevan, 2015; Buckle and Devereux, 2002; Schneider et al., 2010). Occupational risk factors for disorders of the hand and wrist are well researched and associated with exposure to repetitive hand-intensive tasks, especially those involving high levels of force (Palmer et al., 2007; van Rijn et al., 2009). There are guidelines suggesting threshold limit values for exposure–response relationships for occupational physical exposures regarding disorders of the neck and upper limb (Arvidsson et al., 2021; Balogh et al., 2019; Yung et al., 2019). Furthermore, organizational and psychosocial factors are also associated with the neck and upper limb musculoskeletal disorders (Buckle and Devereux, 2002; Devereux et al., 2002; Zare et al., 2021). A high proportion of work-related musculoskeletal disorders are preventable through interventions targeting workplace risk factors (Buckle and Devereux, 2002; Nambiema et al., 2020).

It is reported that interventions to reduce the risk of work-related musculoskeletal disorders are more likely to be effective if they 1) include a multidisciplinary approach, comprising organizational, technical, and personal/individual measures; 2) include a participatory approach, involving workers and their representatives; and 3) are promoted by the management (Podniece et al., 2008; Rivilis et al., 2008). The most effective risk-controlling actions address the exposures, the risk sources, as described in the hierarchy of risk control (Alli, 2008; European Council Directive, 1989; ISO, 2018). For example, job design and organizational strategies, which focus on reducing or eliminating the exposures, are high in the hierarchy, whereas strategies such as information and training workers in work techniques are low in the hierarchy. However, it has been reported that risk-controlling actions for musculoskeletal health mostly focus on changing worker's behaviors, rather than addressing the risk sources (Oakman et al., 2018), even though there is evidence that such actions are ineffective in reducing risk of work-related musculoskeletal disorders (Clemes et al., 2010;

Abbreviations: HIW, Hand-Intensive Work.

* Corresponding author. Occupational and Environmental Medicine, Uppsala University Hospital, 751 85, Uppsala, Sweden.
E-mail addresses: kristina.eliasson@medsci.uu.se (K. Eliasson), charlotte.lewis@umu.se (C. Lewis), Therese.Hellman@medsci.uu.se (T. Hellman), gunilla.dahlgren@umu.se (G. Dahlgren), Magnus.Svartengren@medsci.uu.se (M. Svartengren), Teresia.Nyman@medsci.uu.se (T. Nyman).

https://doi.org/10.1016/j.apergo.2023.104074
Received 11 August 2022; Received in revised form 19 April 2023; Accepted 8 June 2023
Available online 21 June 2023
0003-6870/© 2023 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

Haslam et al., 2007; Hignett, 2003).

In an effort to highlight the adverse consequences of hand-intensive work, with the aim of decreasing the burden of upper limb disorders in Sweden, the Swedish Work Environment Authority, in 2019, introduced an occupational health surveillance targeting hand-intensive work (Arbetsmiljöverket, 2019). The purpose of occupational health surveillances can be regarded as dual: 1) to protect the individual worker by early detection of ill health and 2) to raise awareness of hazardous work environments and thereby identify exposures that need to be controlled. Hence, occupational health surveillances may constitute an important part of occupational health and safety management in an organization. Prior to the legislation coming into force, a process model for the execution of occupational health surveillance for workers exposed to hand-intensive work, abbreviated as "HIW-model" (Fig. 1), was developed (Eliasson et al., 2020). The process model is based on the established risk management process (Identification, Assessment, Control, and Monitoring) (ISO, 2018) in order to clarify that occupational health surveillance should be regarded as a recurrent activity in a company's systematic occupational health and safety management. The model elucidates the interconnection between the exposure assessment and the medical health check. Together, these two components provide information that constitute an immersed risk assessment of how the work environment impacts the workers' health (Eliasson et al., 2020). The intention of the process model is further to support a participative approach in the work environment management. The execution of the model is a workplace based, collaborative process between the representatives of the company (managers, workers, etc.) and the ergonomics expert from the Occupational Health Service provider. The process model aims to support those parties throughout the execution of occupational health surveillance for workers exposed to hand-intensive work, from the identification of hazards to risk-controlling actions and evaluation (Eliasson et al., 2020).

The company representatives and the ergonomists' experiences of the process model were evaluated in terms of feasibility and facilitating or impeding factors affecting the execution of the work process (Eliasson et al., 2021, 2022). Both parties valued being guided by the model throughout the process of the occupational health surveillance. The company representatives stressed that the awareness of musculoskeletal disorders was an important factor for the company to initiate preventive actions in the work environment (Eliasson et al., 2021). This is a finding in accordance with Martinsson et al. (2016), who reported that knowledge of workers' health as well as the capability to evaluate relevant outcome measures after a workplace intervention (which is possible if an exposure assessment is made both prior to and after the risk-controlling actions) raise the incentives to take actions. However, it still remains to explore what specific risk-reducing actions that were proposed, which ones were implemented, and to what extent the implemented actions were evaluated. It also remains to be explored whether the exposed workers experienced any changes in their work environment.

Takala (2018) states that "in real life, management and not the researcher controls the implementation of workplace interventions." Therefore, it is important to explore practitioners' "real" work. Knowledge about whether services result in interventions and positive outcomes or not is important for development of practice. To the best of our knowledge, there are no previous studies exploring the "in real life" practice and outcomes of a work process for occupational health surveillance for the prevention of upper limb disorders. Results from such research can provide valuable knowledge to occupational health practitioners about how to develop their practice in order to support companies in the prevention of upper limb disorders.

The aim of this study was to describe what risk-reducing actions were proposed by ergonomists after the execution of a guided process for occupational health surveillance for workers exposed to hand-intensive work in ten companies. Another aim was to describe the exposed workers' proposals for risk-reducing actions, including their perceptions of potential changes in the self-assessed exposure levels and work-related pain in the neck and upper extremities.

2. Method

2.1. Design

A convergent parallel design was used in this descriptive mixed method study. This means that qualitative and quantitative data were collected and analyzed independently of each other (Creswell, 2014). The study was approved by the Regional Ethical Review Board in Uppsala (project reference number 2017/274).

The sources of data used in this study were: two surveys of workers' perceptions of work-related exposures, exertion during workday and musculoskeletal pain; written reports from ten ergonomists; and interviews with company representatives and ergonomists.

2.2. Study participants and study setting

Ten companies were selected through purposive sampling (Patton, 2014) of companies with workers exposed to hand-intensive work. The participating companies represented different sectors and were located in different regions of Sweden. The ten companies represented the

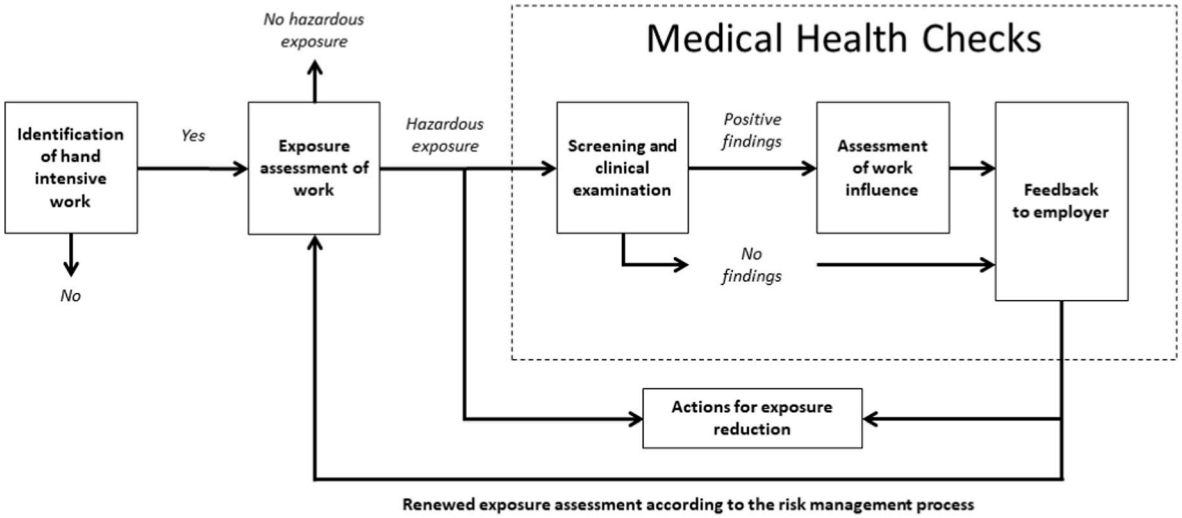


Fig. 1. The process model illustrating the process of occupational health surveillance for workers exposed to hand intensive work.

following sectors: Assembly (n = 4) (e.g., truck components, technology products, automation); painting (n = 1); cleaning (n = 1); food handling (n = 1); dental technology (n = 1); foundry (n = 1) (manual material handling, grinding); and dairy (n = 1) (goods handling). The sizes of the companies were: small, (n = 2, <50 employees), medium (n = 4, >50), and large (n = 4, >250).

Each company formatted a project group, consisting of company representatives such as: first-line manager; Health, Safety- and Environment manager; and safety representative. The number of people in the respective project groups varied, from 3 to 8 people. Moreover, the company's associated occupational health service ergonomist was included in the group. In each project group, one company representative was contact person, both for contacts with the ergonomist as well as with the research team. In total ten ergonomists participated (eight women, two men), one associated to each company. Their age ranged from 32 to 57 years, and their working experience as ergonomists ranged from 5 to 34 years (Eliasson et al., 2021, 2022). Additionally, a group of workers exposed to hand-intensive work from each company was included. At the start of the project, 161 workers (males n = 109, 68% and females n = 52, 32%) participated. Background information for the workers are presented in Table 1. Prior to the start of the study, all participants were informed, verbally and in writing, about the project, and they signed informed consent forms.

The study setting was such that each company selected one department with hand-intensive work in which the occupational health surveillances would be executed, and the work process would follow the HIW-model (Fig. 1). The company's associated ergonomist conducted the exposure assessments of the work tasks in the selected department. The ergonomists' work process with the HIW-model is described in a separate paper (Eliasson et al., 2022). Different observational risk assessment tools were used for the exposure assessment. The medical health checks that followed the exposure assessment included a clinical examination of the exposed workers. The exposure assessment, together with the clinical examination of the exposed workers, constituted a total risk assessment regarding the effect of work on musculoskeletal health. The total risk assessment, together with proposals for risk-reducing actions, was reported to the company representatives. The feedback report would support decisions for the implementation of risk-reducing actions. A detailed presentation of the process is presented in Eliasson et al. (2020).

2.3. Data collection

The data collection consisted of surveys, reports, and interviews during a period of approximately 24 months, as illustrated in Fig. 2.

Two questionnaires (in paper format) were distributed to the workers: at baseline and about one year after the ergonomists had presented their proposals for risk-reducing actions. Thus, the companies had at least one year to implement any action proposals before the follow-up. The questionnaires included questions regarding the perceived work-related exposures, workload, and perceived symptoms in the neck and upper extremities. The questions were formulated according to the validated "standardized Nordic questionnaires for the analysis of musculoskeletal symptoms" (Kuorinka et al., 1987). If perceived symptoms were reported, questions followed as to whether the symptoms were related to the work, and what proposals for actions could reduce the symptoms. The workers' proposals for risk-reducing actions were not reported to the company's representatives but constituted the data for this study. Questions regarding workload were formulated in accordance with questions in the Swedish Work Environmental Authority's bi-annual surveys regarding work environment issues (Arbetsmiljöverket, 2016).

The ergonomists carried out the exposure assessments and medical health checks in the companies between October 2017 and February 2018. Ten feedback reports were collected from the ergonomists (one for each company). The reports included the ergonomist's assessment of the influence of work on musculoskeletal disorders in the examined workers, as well as proposals for risk-reducing actions. The ergonomists had presented the action proposals to the company representatives, both in writing and verbally (Eliasson et al., 2021). The reports varied in layout, scope, and content. Proposals for risk-reducing actions given by the ergonomists constituted data for this study.

Structured follow-up telephone interviews were conducted with the ten ergonomists and with eight contact persons from the companies' project groups, representing companies 3 to 10. Two companies (nos. 1 and 2) lacked representatives in the follow-up interviews. One of the dropouts was due to the HIW-process not fulfilling the contact person's expectations. The other dropout was due to the contact person having terminated employment. The interviews were conducted during autumn 2020, approximately two years after the ergonomist had given the feedback to the company. In total, 18 interviews were conducted, varying in length between 5 and 15 min. The structured interviews were based on an interview guide (separate guides for interviews with company representative, respective, ergonomist). The questions posed to the company representatives were: Have the action proposals been accomplished? How were they implemented? Who was involved in the implementation? Have the effects been evaluated? And if so, what was the outcome? The questions posed to the ergonomists were: Has he/she been involved in further work with the risk-reducing actions following their feedback? If so, how were they involved? What are their reflections about the effects of the actions? All interviews were recorded digitally, and the answers were transcribed.

2.4. Data analysis

Descriptive statistics was used to present the results from the questionnaires regarding the workers' perceived work-related exposures, perceived exertion and the prevalence of perceived pain in the neck and upper extremities. For analyzing potential differences between baseline and follow-up, McNemar's mid-p adjusted binomial paired-sample test for difference in proportions was used. To analyze the differences in the perceived exertion during the workday, paired-sample *t*-test was applied. The statistical analyses were calculated by using SPSS Statistics 27 (IBM, Armonk, NY, USA).

Open-ended questions from the workers' questionnaires, as well as text in the ergonomists' reports, regarding proposals for risk-reducing actions were sorted into three groups, depending on whether the action proposal targeted the organization, technique, or individual/person

Table 1
Descriptive information regarding the employees in the ten participating companies. Number of women/men, mean age (SD), mean years with current work task (SD).

Company no.	1	2	3	4	5	6	7	8	9	10
	Assembly	Painting	Cleaning	Assembly	Assembly	Food handling	Assembly	Dental technology	Foundry	Dairy
Women/Men	6/6	0/11	7/0	10/16	12/10	11/16	0/11	6/6	0/12	0/21
Age	36 (13)	44 (14)	45 (10)	43 (13)	45 (9)	37 (15)	36 (12)	42 (12)	45 (10)	32 (12)
Years with current work task	5 (6)	22 (13)	15 (7)	13 (11)	18 (11)	8 (9)	6 (2)	7 (5)	9 (7)	8 (7)

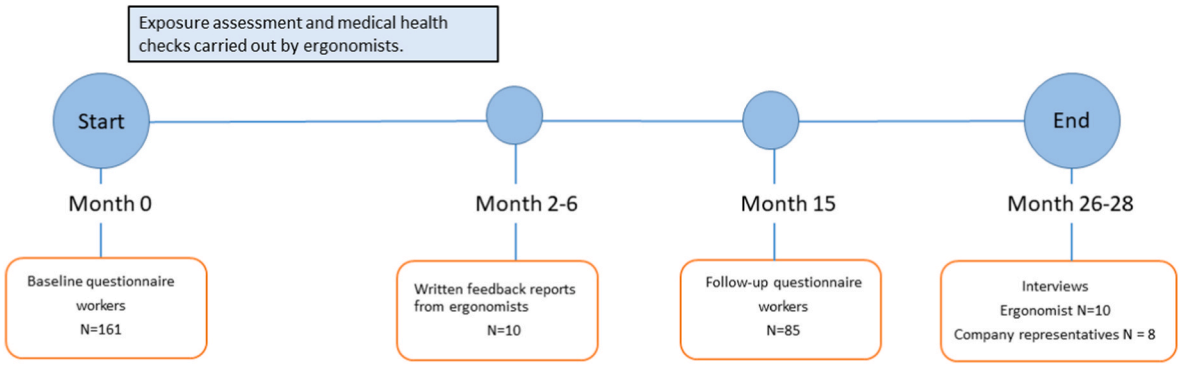


Fig. 2. The figure illustrates the timeline of the data collection with its various data sources and respondents. Exposure assessment and medical health checks were carried out during a period of 2–6 months. Two questionnaires were distributed to the exposed workers before the HIW-process started and followed-up approximately 15 months later. Interviews were conducted approximately 24 months after the feedback reports were submitted.

in the work system.

The interviews with the companies' contact persons and the ergonomists were analyzed by manifest quality content analysis (Elo and Kyngaes, 2008; Graneheim and Lundman, 2004) in order to describe if and how the action proposals were implemented.

3. Results

3.1. Workers' description of exposure and work-related musculoskeletal disorders

The HIA-project targeted companies with manual, hand-intensive work. Table 2 shows the self-reported prevalence of different physical exposures and pain among the employees (N = 161) in the ten participating companies. In all, 81% of the participants (n = 130) reported musculoskeletal symptoms in one or several of the body regions (neck or upper extremities) during the last three months. Details regarding symptoms in the respective body regions are presented in Table 2.

3.2. Proposals for risk-controlling actions, implemented measures, and evaluation

In the baseline survey, the workers were encouraged to suggest action proposals to reduce the risk for musculoskeletal disorders in their workplace. In total, 79 of 161 workers from nine out of ten companies submitted proposals.

Based on their own exposure assessments and clinical examination of the workers, nine out of ten ergonomists presented action proposals to the company representatives. Action proposals from the ergonomists and workers are presented in Table 3.

Table 4 shows which measures were implemented according to the ergonomists and the company representatives, who were interviewed about two years after the ergonomists' action proposals were given to the company. Six companies (nos. 3, 4, 5, 6, 8, 9) implemented some, or all, of the action proposals. The actions were, for the most part, implemented without further consultation with the ergonomist. In two companies (nos. 5 and 9), the ergonomist was engaged in arranging education for the workers in ergonomics awareness training. In company no. 1, the assessed department was totally reorganized after the

Table 2
Baseline prevalence of work-related exposures, perceived exertion during workday, and musculoskeletal pain among the employees in the ten participating companies (N = 161).

	N valid responses	N	%	Mean (SD)	Median (IQR)
Manual handling					
>5 kg	154	108	70	–	–
>15 kg	154	65	42	–	–
Awkward postures (> ¼ of the workday)					
Neck	143	101	71	–	–
Shoulders	144	97	67	–	–
Wrists	150	110	73	–	–
Repetitive movements hand/arm (>10 times/min)	155	80	52	–	–
Constraint work (Y/N)	155	46	30	–	–
Visual demands (Y/N)	154	32	21	–	–
Vibrating tools (>1 h/day)	156	37	24	–	–
Perceived exertion during workday (0–10)					
Neck, shoulders	156	–	–	5,14 (2.04)	5 (2)
Elbow, forearm, hand	156	–	–	4,69 (2.25)	5 (3)
Pain during last three months					
Neck	161	93	58	–	–
Shoulders	161	88	55	–	–
Elbows	160	31	19	–	–
Wrist/Hand	160	84	53	–	–
Fingers	160	63	39	–	–

Table 3
An overview of action proposals according to the ergonomist and the workers. Action proposals sorted into three different groups depending on if the proposal targeted the organization, technique, or individual in the work system. The answers have sometimes been amended to facilitate understanding.

Company/Work Sector	Action proposals	Individual	Technology	Organization
1 Assembly	Ergonomist	Reduce overhand grip.	Adjust work height to reduce lifting over the shoulders or below the knees. Reduce weight in "blue" boxes.	Discuss experience about stress at work. More time for work introduction.
	Workers	*Use "right" tools.* *Different way to insert screws.*	*Adjustable desks.* *Better tools.* *More lifting aids.* *Lifting aids for pallets.* *Raise the floor, lower the assembly line.* *Reduce weight in "blue" boxes.*	*More variety in work through work rotation.* *Lower the tempo, decrease stress.* *Try to influence so that the clutch cylinders are delivered in better packaging.*
2 Painting	Ergonomist	Micro pauses. Ergonomics training. Medical health checks. Use workbenches and other tools to improve work posture.	Purchase wall putty in smaller/lighter packaging to reduce heavy lifting.	Plan for job rotation.
	Workers	*Awareness of movements.* *Awareness of ergonomics.*	*Enable to use correct working height.*	*Inform clients regarding pick away and slide furniture together.* *Job rotation.*
3 Cleaning	Ergonomist	Micro pauses. Reduce grip force. Physical activity during leisure time. Use machine tool. Relaxation/mindfulness. Eye examination.	–	Paper recycling in the corridor not in every room. Request staff to hang up their workplace mats.
	Workers	-	-	-
4 Assembly	Ergonomist	Ergonomics training - recurrent.	Use ergonomic tools. Extra workbench lighting. Change computer monitors position according to recommendations.	Job rotation. Assess and raise awareness of stressors.
	Workers	*Daily stretch routines.* *Vary sitting and standing.*	*Better desks, chairs, and fixtures.* *Better tools.* *Better gloves.* *Lifting aids.* *More adjustable desks.* *Larger workspaces.*	*More job rotation.* *Better packaging from supplier.* *Decrease heavy lifting.* *More staff.* *Improve workplace ergonomics.* *More variety.* *Decrease unnecessary lifting between different packaging containers.*
5 Assembly	Ergonomist	Pauses Work technique training.	–	Job rotation and job enlargement. Ensure pauses being taken.
	Workers	*Work with the material closer to the body, slant the work toward you.* *Vary sitting and standing.* *Movement breaks.* *Massage.*	*Adjustable desks.* *Better aids.* *Decrease vibrations.*	*Reasonable workload in relation to staff.* *Improve employee participation and involvement.* *Reduce the sitting time at the microscope.* *Increase rotation.* *Reduce lifting.*
6 Food handling/ commercial kitchen	Ergonomist	–	–	Job rotation.
	Workers	*Micropauses.* *Reduce stress.* *"Think ergonomics".* *Work more smarter, e.g., less weight with each lift.* *Wrist support.* *Avoid handling cold food.* *Use several layers of cloth gloves under the plastic gloves.*	*Custom equipment.* *Better tools.* *Adjustable work desks.* *More carriages.* *Better gloves for the fridge.*	*Variation in work.* *More staff.* *Better routines, e.g., routines for lifting.* *Reduce stress.* *Wellness hour.* *Avoid handling cold food.*
7 Assembly	Ergonomist	–	–	–
	Workers	*Remember to avoid long intensive work, frequent breaks.* *Awareness of good work technique.*	*Better tools.* *Machines instead of some handheld tools.*	-
8 Dental Technology	Ergonomist	Micro pauses including stretching. Work technique training. Reduced grip.	Use ergonomic tools.	Job rotation.
	Workers	*Massage.* *Frequent breaks.* *Wellness hour.* *Stretching.* *Movement breaks.* *Correct sitting.*	*Adjustable work desks.* *More comfortable chairs.* *Arm support.*	*Reduce stress.* *Encourage to take breaks.* *Vary work tasks.*
9 Foundry	Ergonomist	Ergonomics awareness training in order to: - position/place the goods better. - increase use of lifting aid.	Use low vibrating tools. Control the ventilation system.	Job rotation.

(*continued on next page*)

Table 3 (*continued*)

Company/Work Sector	Action proposals	Individual	Technology	Organization
		- increase understanding of micro pauses. - use the exhaust ventilation system. - Gain knowledge about physical exercise/recovery.		
	Workers	-	*Better tools.* *Better exhaust ventilation system.*	-
10 Dairy	Ergonomist	Ergonomics awareness training including lifting technique.	–	–
	Workers	*Stretching.* *Use better shoes.* *Ergonomic awareness training.* *Lift technique training.*	*Lifting aids.* *Provide better shoes.* *Better, lighter carriages.* *Better floor surface.* *Repair the loading dock.*	*Routines regarding work technique.* *More staff.*

project. However, the reorganization was already planned beforehand and was not a result of the assessment.

The ergonomists' reports did not include any details regarding which exposure the action proposals intended to target or how the actions could be evaluated. Moreover, the interviews revealed that none of the companies evaluated the implemented actions. A common response from the interviewed company representatives was that no evaluations had been done and that they therefore could not say anything about the effects. However, one of the interviewed company manager concluded: "*We have not had a single day of sick leave related to pain in the shoulders, arms, and wrists, at all now in two years*" (Company representative, company no. 4). Another mentioned that the job rotation had resulted in a more stable production. "*When the job rotation follows a good schedule, it leads to a smoother production, resulting in a more predictable production*" (Company representative, company no. 5). One company (no. 9) planned to repeat the clinical examination during the next upcoming year to evaluate the effects regarding the workers' musculoskeletal health.

3.3. Changes in exposure and work-related musculoskeletal pain – results from the follow-up questionnaire

After 15 months, 49% of the workers (N = 85) answered the follow-up survey. Questions regarding work-related exposures, perceived exertion during the workday, and musculoskeletal pain were repeated. Regarding exposure, significant changes were found for decreased repetitive hand movements and manual handling >15 kg (Table 5). Due to the overall small sample size, it was not possible to do stratified analyses separating the 10 companies. However, the diminished proportion regarding repetitive movements in the hand/arm was largest in company 4, in which 11 of 17 workers reported exposure to repetitive movements at the baseline survey and 5 of 11 in the follow-up. No differences were seen regarding musculoskeletal pain or perceived exertion during work (Appendix A).

4. Discussion

The objective of the present study was to explore whether, *in reality*, occupational health surveillance leads to any risk reduction for workers exposed to hand-intensive work. This was investigated by describing what happens when ergonomists and company representatives are introduced to and instructed to follow a work process for occupational health surveillances for workers exposed to hand-intensive work (Fig. 1). Are actions aimed at reducing the risk of upper limb disorders proposed and implemented? Do the implemented actions target exposure so that exposed workers will notice changes?

4.1. Is it likely that the actions proposed could have an effect on the exposure levels?

Six of the participating companies implemented some of the proposed actions. According to the hierarchy of risk control (Alli, 2008; ISO, 2018) measures such as job rotation, improved workstation layout, and improved tools are measures that can impact the exposure levels. Such actions were implemented in three of the companies (nos. 4, 6, 9) (Tables 3 and 4). Company no. 4 implemented improved tools, changes in the workstations, and introduced increased job rotation. Company no. 6 increased the job rotation and company no. 9 improved the tools. (The same company also tried to implement job rotation, but the workers did not appreciate this). Unfortunately, we have no information on whether the job rotation implemented in companies no. 4 and no. 6 actually led to enough/any variation since the companies did not evaluate the implemented actions. When analyzing changes in the self-assessed exposure levels, we, in total, found a significant reduction in the exposure to manual handling >15 kg and repetitive movements in the hand/arm. When excluding all companies that had not implemented any actions which could affect the exposure, we found that company no. 4 was the only one that showed a reduction of exposure to repetitive movements.

The reduced exposure to self-assessed manual handling >15 kg could not be related to any of the implemented action proposals in any company. Consequently, the result indicate that only one company succeeded in implementing actions that reduced the self-assessed exposure to hand intensive work. Since none of the companies evaluated the effect of their implemented actions, even though following an explicit work process (Fig. 1), based on the international policy and practice of a risk management process (Identification, Assessment, Control, and Monitoring) (ISO, 2018), we cannot comment on the effects of the HIW-model as a work method. However, we can conclude that the HIW-model was not fully followed.

This study reveals two major shortcomings in the work process for occupational health surveillance for the prevention of upper limb disorders. First, the risk-controlling actions did not meet the exposure and were not related to the risk-controlling hierarchy and secondly, the implemented actions were not evaluated. The result shows that both ergonomists and companies must improve the connection between work environmental actions and how it will affect hazardous exposure. When ergonomists (or other occupational health consultants) propose different actions to improve the work environment, they also need to guide and support companies in what effect they can expect from the various actions and how these can be evaluated.

In order for occupational health surveillance to be an effective tool for work environment improvements, it is important that they are followed by preventive actions and evaluation of the effectiveness of the implemented actions (Koh and Aw, 2003). There may be several reasons why companies did not evaluate the implemented actions. One reason

Table 4
Implemented actions according to the ergonomist and company representative.

Company no. and sector	
1 Assembly	The selected department was completely reorganized shortly after the ergonomist's feedback. The reorganization was not caused by the results from the feedback. It is not known whether the action proposals were considered in the new organization. The manager has quit; the ergonomist has not been involved in any measures.
2 Painting	No manager participated in the interview. The ergonomist has not been involved in any measures.
3 Cleaning	All proposals were implemented. However, the workplace mats are still not hanged up by some of the staff. The ergonomist was not involved in the measures.
4 Assembly	All proposals, except the "stress awareness" were implemented. Additionally, several other actions were implemented, such as lifting aids, and changes in workstation layout. The company (manager and workers) has been involved in the implementation of the measures. The ergonomist was not involved in the measures.
5 Assembly	Ergonomics awareness training was held shortly after the feedback. The company has tried to encourage the workers to take pauses, but the manager believes that it is not complied with. The company is working to improve job rotation and job enlargement; there is some reluctance among some workers. The ergonomist was involved in the ergonomics education and has provided programs for employees to have active pauses.
6 Food handling/ commercial kitchen	The company has increased job rotation. The ergonomist was not involved in the measures.
7 Assembly	The ergonomist gave no action proposals to the company, so no measures have been taken.
8 Dental Technology	The company has worked with informing and encouraging their workers to take active pauses. No other proposals were implemented. The ergonomist was not involved in the measures.
9 Foundry	All proposals were implemented. However, the job rotation was met by reluctance among the workers, so this was not taken further. The ergonomist was involved in the ergonomics training.
10 Dairy	No measures have been taken.

Table 5
Prevalence of work-related exposures among the employees in the ten participating companies that answered both the baseline and the follow-up questionnaires. McNemar's mid-p adjusted binomial paired-sample test for difference in proportions.

	N valid responses	Baseline N (%)		Follow-up N (%)		p-value
Manual handling						
>5 kg	81	51	63	49	60	0.629
>15 kg	81	30	37	23	28	0.039
Awkward postures (> ¼ of the workday)						
Neck	69	48	70	50	72	0.549
Shoulders	71	47	66	48	68	0.824
Wrists	72	50	69	49	68	0.815
Repetitive movements hand/ arm (>10 times/min)	78	41	53	29	37	0.024
Constraint work (Y/N)	80	21	26	19	24	0.648
Visual demands (Y/N)	82	14	17	14	17	1.000
Vibrating tools (>1 h/day)	83	16	19	21	25	0.210

could be that the overall goal and action metrics are not established; another reason could be that a person responsible for the control and evaluation of actions was not designated. All of this indicates that there was a lack of experience and/or skills among the participants, namely the occupational ergonomists and the company representatives, when it comes to working in a participatory process.

Further, the results show a discrepancy between the workers' and the ergonomists' action proposals. The qualitative description shows that workers have more proposals targeting technology and organization (Table 3), which is not surprising since they know their workplace and know what actions will help them to reduce the exposure. Two companies (nos. 1 and 4) had received action proposals targeting psychosocial hazards but had not addressed those. It is important to include actions targeting psychosocial hazards, such as stress, since it is evident that psychosocial hazards as well as biomechanical hazards are related to musculoskeletal disorders (da Costa and Vieira, 2010; Lang et al., 2012). Earlier research has reported that managers are not aware of the relation between psychosocial hazard and musculoskeletal disorders (Oakman et al., 2019). The result from this study confirms other studies which have highlighted that the current risk management practices for the prevention of musculoskeletal disorders fail to address the psychosocial hazards (Macdonald and Oakman, 2015, 2022; Robertson et al., 2021; Whysall et al., 2004).

The HIW-model was supposed to support a participatory process, and the company representatives as well as the ergonomists have expressed that they value the joint process, e.g., by working together toward a common goal (Eliasson et al., 2021, 2022). However, the results in the present study, together with findings from the previous studies exploring company representatives' and ergonomists' experiences of the HIW-model (Eliasson et al., 2021, 2022), show that the HIW-model needs to be improved in order to support and guide ergonomists and company representatives in a participatory process, from the identification of hazards to risk-controlling actions and evaluation. For example, the workers' action proposals were not considered in the HIW-model, this should be included in future development of the model.

Furthermore, the results from all three studies show the importance of clarity regarding roles and responsibilities in the process. A solution might be to put together a risk management team in the workplace, responsible for the development of action proposals, implementation, and evaluation. Oakman and Macdonald (2019) describe the role of a risk management team to facilitate the integration of managing risks for musculoskeletal disorders into a broader system of risk management. As we can see in the present study, no one took the responsibility for evaluating the actions. A risk management team, in which roles and responsibilities are clear, might facilitate the implementation and evaluation of actions. A risk management team could, in this case, consist of e.g., manager (senior and first line), worker's representative, and ergonomist. These individuals could work together in order to prioritize actions for implementation and set the evaluation metrics.

4.2. Strengths and limitations

The convergent parallel design used in this mixed method study included data from surveys, interviews, and documents, which made it possible to present experiences from three different perspectives (workers, company representatives, and ergonomists). In this research

project, the researchers have not been involved in how the process was executed, as we wanted to explore the "*real work*." Descriptive studies such as this are important in order to gain an understanding of the knowledge gaps that need to be further addressed.

In this study, the included companies represented different sectors, and there were differences between the companies' organizations regarding work with occupational health and safety issues. Some of the companies had access to limited in-house work environment expertise, and some companies had internal occupational health and safety departments providing work environment expertise. The ergonomists also differed regarding earlier contact with the company and experiences of similar work. These factors could have had an impact on how the HIW-model was executed and action proposals implemented. However, those factors are not evaluated in this study.

Despite the heterogeneity of both companies and ergonomists in the present study, the results unanimously show that evaluations of implemented measures were lacking, something that increases the transferability of the results (Graneheim et al., 2017; Shenton, 2004).

It can be questioned whether it is relevant to explore and include workers' perceived health, given the multifactorial and intermittent nature of neck and upper limb disorders, as well as the groups in each company being small (7–27 individuals). As expected, there were no changes regarding pain. However, it is a strength of the present study that changes in exposure were explored through the workers' perspective. Accordingly, we could get an indication of whether the implemented actions led to reduced exposure.

The results of this study give no indication whether the new regulation for occupational health surveillance targeting hand-intensive work (Arbetsmiljöverket, 2019) is an effective way to reduce the prevalence of neck and upper limb disorders among workers. It is possible that there will be a decrease in the number of neck and upper limb disorders once the regulation has been in place for some years. The effect of the regulation at a group level needs to be further studied with other study designs.

5. Conclusions

This study showed that the HIW-model guided process for occupational health surveillance for workers exposed to hand-intensive work resulted in several action proposals, targeting organizational, technical, and/or personal/individual measures, which were proposed by the ergonomists to the company representatives. Six of the ten participating companies implemented at least one of the action proposals. However, action proposals were not related to any evaluation metrics, and the implemented action proposals were not evaluated by the companies.

The study also revealed that action proposals from the ergonomists more often targeted personal/individual measures (such as behavioral changes), whereas the workers more often listed action proposals targeting technology or organization. Hence, one can conclude that there is a great potential to make better use of the workers' proposals by involving workers more in the risk management process.

We conclude that the HIW-model provides support in the occupational health surveillance process, but the anchoring of the process needs to be strengthened, for example, by having a risk management team responsible for implementation. Furthermore, this study shows that guidance is needed for evaluation of implemented actions, so that all parts of the risk management process are met.

Funding

This work was supported by the Swedish Work Environment Authority (Project no. 2015/033753).

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.

Acknowledgments

The authors gratefully acknowledge the participating company representatives, workers, and ergonomists for sharing their experiences. Furthermore, we would like to acknowledge Associate Professor Catarina Nordander and Lotta Löfqvist, Ph.D. at Lund University, for their valuable contributions with participant recruitment and planning of the research project.

Appendix A

Analysis regarding workers' self-assessed changes in the exposure and work-related musculoskeletal pain in the neck and the upper limbs.

Table 1
Prevalence of musculoskeletal pain during the last seven days among the employees in the ten participating companies that answered both the baseline and the follow-up questionnaires. McNemar's mid-p adjusted binomial paired-sample test for difference in proportions.

	N valid responses	Baseline N (%)		Follow-up N (%)		p-value
Neck	83	35	42	35	42	1.000
Shoulders	82	28	34	28	34	1.000
Elbows	83	13	16	10	12	0.424
Wrist/Hand	80	27	34	24	30	0.481
Fingers	80	21	26	22	28	0.832

Table 2
Perceived exertion during the workday (0–10) among the employees in the ten participating companies that answered both the baseline and the follow-up questionnaires. Paired-sample *t*-test.

	N valid responses	Baseline mean (SD)		Follow-up mean (SD)		p-value
Perceived exertion during *the* workday (0–10)						
Neck, shoulders	81	4.88	1.77	4.73	2.09	0.474
Elbow, forearm, hand	82	4.40	2.19	4.13	2.26	0.253

References

Alli, B.O., 2008. Fundamental Principles of Occupational Health and Safety, second ed. International Labour Office, ILO, Geneva.

Arbetsmiljöverket, 2016. Arbetsmiljön 2015 [The Work Environment 2015], Arbetsmiljöstatistik Rapport 2016:2. Arbetsmiljöverket [Swedish Work Environment Authority]. https://www.av.se/globalassets/filer/statistik/arbetsmiljon-2015/arbetsmiljostatistik-arbetsmiljon-2015-rapport-2016-2.pdf. (Accessed 19 June 2022).

Arbetsmiljöverket, 2019. AFS 2019:3 Medicinska Kontroller I Arbetslivet. [Provision AFS 2019:3. Occupational Health Surveillance]. Arbetsmiljöverket [Swedish Work Environment Authority].

Arvidsson, I., Dahlqvist, C., Enquist, H., Nordander, C., 2021. Action levels for the prevention of work-related musculoskeletal disorders in the neck and upper extremities: a proposal. Ann. Work expo. Health 65, 741–747. https://doi.org/10.1093/annweh/wxab012.

Balogh, I., Arvidsson, I., Bjork, J., Hansson, G.A., Ohlsson, K., Skerfving, S., Nordander, C., 2019. Work-related neck and upper limb disorders - quantitative exposure-response relationships adjusted for personal characteristics and psychosocial conditions. BMC Muscoskel. Disord. 20, 139. https://doi.org/10.1186/s12891-019-2491-6.

Barr, A.E., Barbe, M.F., Clark, B.D., 2004. Work-related musculoskeletal disorders of the hand and wrist: epidemiology, pathophysiology, and sensorimotor changes. J. Orthop. Sports Phys. Ther. 34, 610–627. https://doi.org/10.2519/jospt.2004.34.10.610.

Bevan, S., 2015. Economic impact of musculoskeletal disorders (MSDs) on work in Europe. Best Pract. Res. Clin. Rheumatol. 29, 356–373. https://doi.org/10.1016/j.berh.2015.08.002.

Buckle, P.W., Devereux, J.J., 2002. The nature of work-related neck and upper limb musculoskeletal disorders. Appl. Ergon. 33, 207–217. https://doi.org/10.1016/s0003-6870(02)00014-5.

Clemes, S.A., Haslam, C.O., Haslam, R.A., 2010. What constitutes effective manual handling training? A systematic review. Occup. Med. 60, 101–107. https://doi.org/10.1093/occmed/kqp127.

Creswell, J.W., 2014. Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, fourth ed. SAGE.

da Costa, B.R., Vieira, E.R., 2010. Risk factors for work-related musculoskeletal disorders: a systematic review of recent longitudinal studies. Am. J. Ind. Med. 53, 285–323. https://doi.org/10.1002/ajim.20750.

Devereux, J.J., Vlachonikolis, I.G., Buckle, P.W., 2002. Epidemiological study to investigate potential interaction between physical and psychosocial factors at work that may increase the risk of symptoms of musculoskeletal disorder of the neck and upper limb. Occup. Environ. Med. 59 (4), 269–277. https://doi.org/10.1136/oem.59.4.269.

Eliasson, K., Palm, P., Nordander, C., Dahlgren, G., Lewis, C., Hellman, T., Svartengren, M., Nyman, T., 2020. Study protocol for a qualitative research project exploring an occupational health surveillance model for workers exposed to hand-intensive work. Int. J. Environ. Res. Publ. Health 17 (17), 6400. https://doi.org/10.3390/ijerph17176400.

Eliasson, K., Dahlgren, G., Hellman, T., Lewis, C., Palm, P., Svartengren, M., Nyman, T., 2021. Company representatives' experiences of occupational health surveillance for workers exposed to hand-intensive work: a qualitative study. Int. J. Environ. Res. Publ. Health 18 (4). https://doi.org/10.3390/ijerph18042018, 2018.

Eliasson, K., Fjellman-Wiklund, A., Dahlgren, G., Hellman, T., Svartengren, M., Nyman, T., Lewis, C., 2022. Ergonomists' experiences of executing occupational health surveillance for workers exposed to hand-intensive work: a qualitative exploration. BMC Health Serv. Res. 22, 1223. https://doi.org/10.1186/s12913-022-08601-2.

Elo, S., Kyngaes, H., 2008. The qualitative content analysis process. J. Adv. Nurs. 62 (1), 107–115. https://doi.org/10.1111/j.1365-2648.2007.04569.x.

European Council Directive, 1989. Council Directive of 12 June 1989 on the Introduction of Measures to Encourage Improvements in the Safety and Health of Workers at Work, 89/391/EEC. European Council, Brussels, Belgium.

Graneheim, U.H., Lundman, B., 2004. Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness. Nurse Educ. Today 24, 105–112. https://doi.org/10.1016/j.nedt.2003.10.001.

Graneheim, U.H., Lindgren, B.-M., Lundman, B., 2017. Methodological challenges in qualitative content analysis: a discussion paper. Nurse Educ. Today 56, 29–34. https://doi.org/10.1016/j.nedt.2017.06.002.

Haslam, C., Clemes, S., McDermott, H., Shaw, K., Williams, C., Haslam, R., 2007. Manual Handling Training: Investigation of Current Practices and Development of Guidelines. HMSO, Norwich. Research report RR583. https://hdl.handle.net/2134/8353.

Hignett, S., 2003. Intervention strategies to reduce musculoskeletal injuries associated with handling patients: a systematic review. Occup. Environ. Med. 60 (9), E6. https://doi.org/10.1136/oem.60.9.e6.

ISO, 2018. Risk Management - Guidelines. ISO 31000:2018).

Koh, D., Aw, T.-C., 2003. Surveillance in occupational health. Occup. Environ. Med. 60, 705–710. https://doi.org/10.1136/oem.60.9.705.

Kuorinka, I., Jonsson, B., Kilbom, A., Vinterberg, H., Biering-Sorensen, F., Andersson, G., Jorgensen, K., 1987. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Appl. Ergon. 18, 233–237. https://doi.org/10.1016/0003-6870(87)90010-x.

Lang, J., Ochsmann, E., Kraus, T., Lang, J.W.B., 2012. Psychosocial work stressors as antecedents of musculoskeletal problems: a systematic review and meta-analysis of stability-adjusted longitudinal studies. Soc. Sci. Med. 75, 1163–1174. https://doi.org/10.1016/j.socscimed.2012.04.015.

Macdonald, W., Oakman, J., 2015. Requirements for more effective prevention of work-related musculoskeletal disorders. BMC Muscoskel. Disord. 16, 1–9. https://doi.org/10.1186/s12891-015-0750-8.

Macdonald, W., Oakman, J., 2022. The problem with "ergonomics injuries": what can ergonomists do? Appl. Ergon. 103, 103774 https://doi.org/10.1016/j.apergo.2022.103774.

Martinsson, C., Lohela-Karlsson, M., Kwak, L., Bergstrom, G., Hellman, T., 2016. What incentives influence employers to engage in workplace health interventions? BMC Publ. Health 16, 854. https://doi.org/10.1186/s12889-016-3534-7.

Nambiema, A., Bertrais, S., Bodin, J., Fouquet, N., Aublet-Cuvelier, A., Evanoff, B., Descatha, A., Roquelaure, Y., 2020. Proportion of upper extremity musculoskeletal disorders attributable to personal and occupational factors: results from the French Pays de la Loire study. BMC Publ. Health 20, 456. https://doi.org/10.1186/s12889-020-08548-1.

Oakman, J., Macdonald, W., 2019. The APHIRM toolkit: an evidence-based system for workplace MSD risk management. BMC Muscoskel. Disord. 20, 504. https://doi.org/10.1186/s12891-019-2828-1.

Oakman, J., Macdonald, W., Bartram, T., Keegel, T., Kinsman, N., 2018. Workplace risk management practices to prevent musculoskeletal and mental health disorders: what are the gaps? Saf. Sci. 101, 220–230. https://doi.org/10.1016/j.ssci.2017.09.004.

Oakman, J., Macdonald, W., Kinsman, N., 2019. Barriers to more effective prevention of work-related musculoskeletal and mental health disorders. Appl. Ergon. 75, 184–192. https://doi.org/10.1016/j.apergo.2018.10.007.

Palmer, K.T., Harris, E.C., Coggon, D., 2007. Carpal tunnel syndrome and its relation to occupation: a systematic literature review. Occup. Med. 57, 57–66. https://doi.org/10.1093/occmed/kql125.

Patton, M.Q., 2014. Qualitative Research & Evaluation Methods: Integrating Theory and Practice, 4 ed. Sage publications.

Podniece, Z., Heuvel, S., Blatter, B., 2008. Work-related Musculoskeletal Disorders: Prevention Report. European Agency for Safety and Health at Work.

Rivilis, I., Eerd, D., Cullen, K., Cole, D., Irvin, E., Tyson, J., 2008. Effectiveness of participatory ergonomic interventions on health outcomes: a systematic review. Appl. Ergon. 39, 342–358. https://doi.org/10.1016/j.apergo.2007.08.006.

Robertson, J., Jayne, C., Oakman, J., 2021. Work-related musculoskeletal and mental health disorders: are workplace policies and practices based on contemporary evidence? Saf. Sci. 138, 105098 https://doi.org/10.1016/j.ssci.2020.105098.

Schneider, E., Irastorza, X., Copsey, S., 2010. OSH in Figures: Work-Related Musculoskeletal Disorders in the EU — Facts and Figures. Publications Office of the European Union, Luxembourg.

Shenton, A.K., 2004. Strategies for ensuring trustworthiness in qualitative research projects. Educ. Inf. 22, 63–75. https://doi.org/10.3233/EFI-2004-22201.

Takala, E.P., 2018. Ergonomic interventions and prevention - a need for better understanding of implementation [Editorial]. Scand. J. Work. Environ. Health 44, 111–112. https://doi.org/10.5271/sjweh.3710.

van Rijn, R.M., Huisstede, B.M., Koes, B.W., Burdorf, A., 2009. Associations between work-related factors and the carpal tunnel syndrome-a systematic review. Scand. J. Work. Environ. Health 35, 19–36. https://doi.org/10.5271/sjweh.1306.

Whysall, Z.J., Haslam, R.A., Haslam, C., 2004. Processes, barriers, and outcomes described by ergonomics consultants in preventing work-related musculoskeletal disorders. Appl. Ergon. 35, 343–351. https://doi.org/10.1016/j.apergo.2004.03.001.

Yung, M., Dale, A.M., Kapellusch, J., Bao, S., Harris-Adamson, C., Meyers, A.R., Hegmann, K.T., Rempel, D., Evanoff, B.A., 2019. Modeling the effect of the 2018 revised ACGIH hand activity Threshold Limit Value (TLV) at reducing risk for carpal tunnel syndrome. J. Occup. Environ. Hyg. 16, 628–633. https://doi.org/10.1080/15459624.2019.1640366.

Zare, A., Choobineh, A., Hassanipour, S., Malakoutikhah, M., 2021. Investigation of psychosocial factors on upper limb musculoskeletal disorders and the prevalence of its musculoskeletal disorders among nurses: a systematic review and meta-analysis. Int. Arch. Occup. Environ. Health 94, 1113–1136. https://doi.org/10.1007/s00420-021-01654-6.