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Effectiveness of Participatory Ergonomic Interventions

A systematic review
Volume 2

About this report:

Authors: Donald Cole[1,2], Irina Rivilis[1], Dwayne Van Eerd[1], Kimberley Cullen[1], Emma Irvin[1], Dee Kramer[1]

Steering Committee: Donald Cole, Irina Rivilis, Dwayne Van Eerd, Kimberley Cullen, Jonathan Tyson [3], Emma Irvin Quenby Mahood [1]

Reviewers: Donald Cole, Kimberley Cullen, Irina Rivilis, Emma Irvin, Jonathan Tyson, Dwayne Van Eerd

Library Staff: Emma Irvin, Quenby Mahood, Doreen Day [1], Dan Shannon [1]

Administrative Assistant: Elizabeth Resendes [1]

1 Institute for Work & Health, Toronto, Ontario, Canada
2 University of Toronto, Toronto, Ontario, Canada
3 Pulp and Paper Health and Safety Association, North Bay, Ontario, Canada

If you have a question about this or any other of our reports, please contact us at:

Institute for Work & Health
481 University Avenue, 8th Floor
Toronto, Ontario M5G 2E9

E-mail: info@iwh.on.ca

Or you can visit our web site at www.iwh.on.ca.

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Introduction

Work related musculoskeletal disorders (MSD) are responsible for considerable financial costs in the form of worker compensation claims, medical assistance, and lost productivity (76). As well, the health and financial burden of MSD extends beyond that demonstrated in administrative databases, as it affects workers, their families, the medical system, and society in general (4; 66).

It has been recognized that poor ergonomics, particularly inappropriate design of equipment, workplaces and work processes, can result in important risk factors for MSD and the disability that ensues (5; 28; 52). Consequently, workplace ergonomic interventions have garnered interest as a means of improving working conditions, occupational health, and productivity. For example, a recent Occupational Health and Safety Council of Ontario (OHSCO) initiative is exploring the claims costs associated with MSD and the implementation of ergonomic strategies to reduce the number of MSD claims submitted by Ontario workers (56).

Participatory Ergonomic (PE) approaches grew out of quality circle experiences in Japan (50) and participatory workplace design processes in Northern Europe (22) and North America (43) during the 1980s. Unions (13), health and safety sectoral agencies (3), and health and safety associations (53) have actively promoted PE approaches. Wells et al. (70) and researchers from the Centre for Research Expertise on the Prevention of Musculoskeletal Disorders and Disability (cre-PREMUS) have advocated the use of a PE blueprint specifically developed to guide PE interventions. Interventions using this blueprint have been implemented in several manufacturing workplaces in Southern Ontario and are being adapted by Ontario health and safety associations (34).

I 1 Scientific literature on Participatory Ergonomics

The number of studies examining PE approaches reported in the scientific literature grew substantially during the 1990s, as can be seen in the bibliometric analysis by year of publication for the articles identified in this review (Figure I.1).

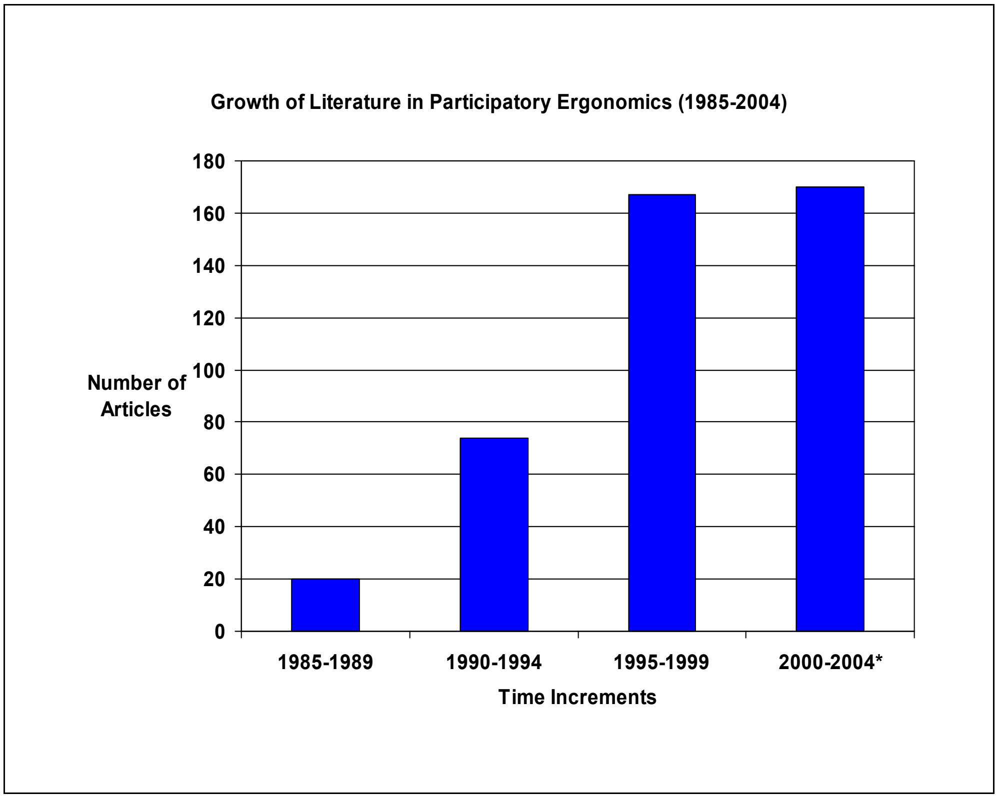

Figure I.1 Bibliometric data on articles on PE by year of publication (*to July 2004)

Building on this growth in literature, important narrative reviews on experiences with ergonomic interventions (29; 61; 30; 32) have reflected upon how to better frame or implement PE interventions. In policy circles, substantial judgments have been made about the effectiveness of ergonomic interventions in general (26) yet the evidence supporting the effectiveness of PE interventions in decreasing MSD per se has not been summarized. A systematic evaluation of the quality, quantity and consistency of evidence of effectiveness of PE has not been reported in the scientific literature. Hence, a systematic review of the scientific literature on the effectiveness of PE was thought to be valuable for practitioners, policy makers and researchers interested in PE interventions.

I 2 Concept of Participatory Ergonomics

Examining the effectiveness of PE requires some understanding of the constituent characteristics of PE. PE has been defined as "the involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals" (75), and more recently by Kourinka (38) as "practical ergonomics with participation of the necessary actors in problem solving". These definitions are often accompanied by a description of the various elements or dimensions of PE (30).

A characteristic feature of PE is the formation of an ergonomics 'team' which guides the intervention process. The team is typically made up of employees or their representatives, managers, ergonomists, health and safety personnel, and research experts. This can be considered as a means of using an organization's experience together with expert input to devise the best possible interventions (51). Newly formed teams typically undergo training by an expert (usually an ergonomist) to become familiar with ergonomic principles. With a foundation of ergonomic concepts and methods in place, the group uses their newly developed knowledge in making improvements in their workplace (29; 57).

Work organization and psychosocial factors are risk factors for MSD (71; 7; 44). Therefore it is important for PE interventions to have both employee and management participation in identifying and implementing changes (50; 30). By working together to improve workplace conditions through participation, communication, and group problem solving, a PE intervention can positively impact on the organization's culture as well as worker's health (40; 62). Ideally, the PE approach encourages workers to be involved in controlling their own work activities. This may decrease work organization risk factors (38). Moreover, PE aims to develop the problem solving capabilities needed to improve working conditions, facilitate communication among workplace parties, and promote acceptance of change by the workforce (70; 31; 29; 75).

I 3 Scope of the review

The prerequisites and benefits of implementing successful PE programs have been described (50; 75). However evaluations often focus on particular aspects of PE, with only a subset of evaluations focusing on employee health. We can conceive of a number of steps along a pathway by which PE might improve both employee health and productivity as per Figure I.2.

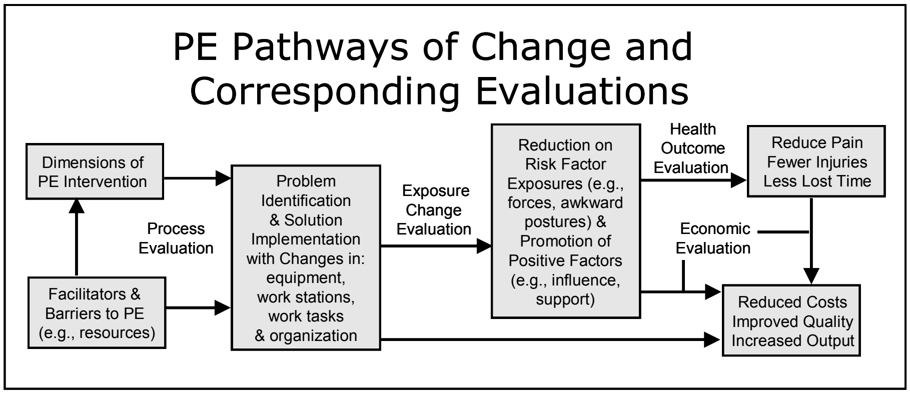

Figure I.2 PE Pathways of change and corresponding Evaluations

Process evaluation of PE implementation is important for understanding how changes are brought about. Qualitative and quantitative literature on PE processes is available (39; 58), relevant to those with a primary interest in how to improve ways of implementing PE. Although this is of interest to practitioners, a systematic review would pose the research question differently to address the success of the process in making effective changes.

Similarly a literature exists on the effectiveness of PE in reducing exposures or risk factors for MSD i.e., *exposure change evaluations*. For example, a randomized controlled trial by Straker and colleagues (65) demonstrated reductions in a variety of important indicators of biomechanical exposure. Such changes in exposure are important to overall judgments of the effectiveness of PE (16) and as such are included in our quality criteria (see section M3). However, given our primary interest in *health outcome evaluations*, we decided against expanding the review to answer sub-questions addressing exposure reductions.

Finally, a nascent formal *economic evaluation* literature on the efficiency of workplace interventions in achieving changes in both employee health and production outcomes is developing (21). Questions in a review of economic evaluations address the relative cost-benefit of implementing PE in different kinds of workplaces. The relative paucity of available studies on PE alone and the additional disciplinary skills required precluded our inclusion of studies focusing solely on economic outcomes. However, studies which included both economic analyses based on reported health outcomes were included though our focus remained on methodological strengths for PE effectiveness in improving health outcomes.

In summary, we recognize the importance of assessing process and exposure reduction for improving health outcomes within a broader evaluation theory perspective and we understand the importance of economic outcomes for workplace parties and policy makers. Nevertheless, based upon resource and time constraints, we limited the scope of this systematic review to *health outcome evaluation*.

I 4 Objectives of the Systematic Review

The *first* objective of this review was to synthesize evidence on the effectiveness of workplace-based participatory ergonomic (PE) interventions in improving health outcomes. Effectiveness was determined by examining quantitative evidence regarding achievement of the desirable consequences, such as reduced levels of musculoskeletal (MSK) pain or discomfort, injuries or claims and time loss.

The *second* objective was to provide an assessment of the methodological strengths and weaknesses which characterize the quantitative health outcome evaluation studies conducted on PE interventions in order to provide guidance for future research and evaluation.

I 5 Organization of the report

We follow this introduction with a detailed description of the methods used to conduct the selection, quality appraisal, data extraction and best evidence synthesis of the quantitative studies. Our findings include sections on: the number of studies found, the quality and methodological strengths observed; the characteristics of PE interventions, changes identified or implemented, barriers and facilitators of implementation, risk factors identified, health outcomes observed, other outcomes extracted from the studies reviewed and the synthesis of evidence regarding PE for different health outcomes. We conclude the document with recommendations for future PE research and evaluation.

Methods

M 1 Literature Search
The following electronic databases were searched from their inception until July 2004: MEDLINE (from 1966), EMBASE (from 1980), Cumulative Index to Nursing & Allied Health Literature (CINAHL, from 1982), Canadian Centre for Occupational Health and Safety (CCINFO web), Safety Science and Risk (from 1981), and Ergonomic Abstracts (from 1969). Since the search terms and languages of the databases differed significantly, the terms used in the search were customized for each database. The search was limited to English language sources since we did not have a minimum of two reviewers competent in any other language. A copy of our general search strategy can be found in Appendix Table M.1.

Databases were searched for articles satisfying four general criteria for inclusion: the presence of an intervention, the use of ergonomics, the use of participatory techniques, and the presence of health outcomes. The search strategy combined these four sets of keywords using an "AND" strategy (Appendix Figure M.1), the terms within each group were OR'd. For the most part, the titles, abstracts, case registry or subject headings were all searched for keywords. However, due to the different algorithms employed by the different databases this was not always the case. In addition, the reference lists of all papers selected for review were manually searched. Conference proceedings were excluded because most are not peer reviewed, and because of insufficient information that is usually provided in proceedings to adequately assess quality and extract data for review compared to journal articles.

The search strategy was designed to be inclusive and identify as many relevant studies as possible. We were aware that the search strategy may capture non-relevant studies; therefore subsequent steps in the review process were designed to identify and omit non-relevant studies from further review.

M 2 Selection for Relevance
Titles and abstracts of each article were screened by at least two reviewers. Full text articles were retrieved for those studies that appeared to meet the inclusion and exclusion criteria (Table M.2.), and for those in which insufficient information was presented in the title, abstract, and key words to determine eligibility. Disagreements between the two reviewers were discussed until agreement could be reached. When agreement could not be reached between the initial two reviewers, a third reviewer was consulted to come to a resolution about relevance.

Judgements about the participatory approach were often difficult to make. The inclusion and exclusion statements represent the two extremes of a range of participation. We considered all studies that did not meet the exclusion criteria. This enabled us to review studies employing a range of participation approaches.

Table M.2 Criteria for inclusion and exclusion of studies

	Inclusion	Exclusion
Publication Type	• Journal articles that are peer reviewed	• Magazine articles (including all works that are published in a format aimed at an educated lay audience, in contrast with those reporting on research aimed at an academic audience) • Book chapters • Conference proceedings • Dissertations • Non peer reviewed publications
Population of interest	• Any working population	• Any populations that are not of working age (adolescents, retired, etc.) or are not actively participating in the workforce
Presence of Intervention	• An intervention/change process had to occur	• No changes were carried out • Papers describing best practices, or methods were to be excluded
Ergonomics	• Intervention must be of ergonomic nature or have something to do with work design. • Ergonomics was defined as contributing to the design and evaluation of tasks, jobs, products, environments and systems in order to make them compatible with the needs, abilities and limitations of people	• Other types of interventions that do not utilize ergonomics. Examples of exclusions include health promotion interventions such as smoking cessation programs, workplace exercise programs, cognitive ergonomics, occupational health services or disability management interventions that do not use ergonomics
Participatory Approach	• Interventions must be participatory or utilize participatory principles. • Participatory approach defined as the involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals. • Training/knowledge are important elements of the intervention process	• No direct or indirect involvement of the end users of the intervention in the intervention process. For example, an intervention carried out solely by consultants external to the workplace and does not use worker/management input, is to be excluded as it is not considered to be participatory
Outcomes	• At least one health outcome had to be measured for evaluation purposes. One of the following outcomes must be included in the study to be considered relevant: pain/discomfort, musculoskeletal symptoms, injury rates, accident/first aid rates, absenteeism, sick leave, or work function/limitation	• No health outcomes of interest are reported
Languages	• English only	

M 3 Quality Appraisal

We developed our quality criteria to apply to a broad range of research designs (27). We sought strong experimental designs such as randomized controlled trials (RCTs) but encountered very few. However RCTs tend to be challenging, complex interventions which may not be feasible in workplaces given their requirement for investigator control and generally high cost. Therefore we also included quasi-experimental designs with non-random control groups or longitudinal data collection (18; 27; 37) because often workplace parties must be involved in decisions on participation and the timing of interventions. Hence, our quality criteria were based on both design-specific quality appraisal systems typically found in systematic reviews (8; 20; 55) and newly emerging systems from the literature focusing on interventions (77).

Our quality appraisal (QA) form (see Appendix M.3 materials) drew on previous work by Franche et al. (25), Côté et al. (19; 20), Oxman & Guyatt (55), Smith et al. (64), and Zaza et al. (77). Included was information pertinent to 27 QA criteria in the following categories: study design, study population, level of recruitment, study objectives, exposure to intervention, intensity of intervention process, risk factors/exposures, health outcomes, potential confounders, and statistical analyses. Criteria were developed to be applicable to all studies regardless of design. Two final questions asked about confidence in the reported effects of the study and whether the study should go on to data extraction, with reasons for each. Each relevant study was quality assessed independently by rotating pairs of reviewers, followed by a meeting of the pair to discuss any disagreements. If agreement could not be reached about relevance, a third reviewer was brought in to achieve consensus on criteria and whether a study was suitable for data extraction (DE).

Study ratings on the QA criteria were compared between those studies that were judged appropriate for DE and those that were not (non-DE). Each criterion was rated on a three-point scale, regarding its importance in the decision to proceed to DE, ranging from 'not important' to 'very important'. The QA criteria rated as 'important' (n=5) or 'very important' (n=11) are listed below in Table M 3.2. The majority assess aspects of internal validity applicable across all study designs. Many are also important for replication and application in other settings (i.e., they are relevant to external validity). The latter is particularly important for complex workplace preventive or health promoting interventions as discussed by Bull and colleagues (11).

Table M.3.2 Quality appraisal (QA) criteria importance for suggested data extraction (DE) and decision on methodological strength (MS) criteria

QA criteria	Importance for DE Suggestion	MS Criteria #
Clearly stated research question/objective	Important	-
Multiple levels of recruitment	Important	-
Description of baseline characteristics at each level	Very Important	(1)
Concurrent comparison groups used	Very Important	(2)
Intervention allocation described	Important	-
Randomized allocation used	Very Important	(3)
Participation in intervention documented	Very Important	(4)
Multiple levels involved in decisions around changes	Important	-
Changes resulting from the intervention documented	Very Important	(5)
Co-interventions and/or contamination described	Very Important	(6)
Risk factors for musculoskeletal disorders measured	Very Important	(7)
Risk factors measured at baseline and follow-up	Very Important	-
Health outcomes measured at baseline and follow-up	Important	(8)
Potential confounders measured	Very Important	(9)
Appropriate statistical analyses conducted	Very Important	(10)
Adjustment for relevant baseline differences	Very Important	(11)

Of the 16 criteria in Table M.3.2, eleven were deemed to be critical for adequate internal validity. These were designated 'methodological strength (MS) criteria' (last column of table M.3.2). Based on these MS criteria, four quality categories were developed:

- Very High – 100% of MS criteria met
- High -75 – 99% of MS criteria met,
- Medium – 45 – 74% of MS criteria met
- Low – 0 – 44% of MS criteria met.

Each study was assigned a rating from this scale. Only studies which were rated 'medium' or higher i.e., met 45% or more of the MS criteria, went on to data extraction (DE).

M 4 Data extraction

Standardized data extraction forms were developed by the review team, based on existing forms and data extraction procedures (25; 64; 77) (see Appendix M4 for the DE guide to reviewers on completing the forms). The pairs of reviewers extracted data on: year of study, jurisdiction, industry sector, study design (according to Zaza et al. (77)), study participant characteristics, follow-up time, risk factors considered, health outcome measures, statistical analyses, health outcome findings, co-interventions, facilitators/barriers, confounders, non-health measures, and non-health outcome findings. In addition the reviewers extracted detailed information about the interventions employed.

M 5 Evidence synthesis

A number of frameworks are available for synthesis of evidence. We had to consider synthesis approaches which were applicable to a diversity of disciplinary backgrounds in those evaluating PE interventions and a potentially broad range of epidemiological rigour in the studies of PE. We also needed to use synthesis approaches which were applicable to health but were not discipline-specific e.g., Rychetnik et al. (61), Task Force on Community Preventive Services (10), Ontario Effective Public Health Practice Project (54), and the American Journal of Preventive Medicine (1) special issue on injury prevention interventions.

Further, we needed to be able to accommodate substantial heterogeneity in the studies proceeding to data extraction. They came from different countries, carried out different kinds of PE interventions, focused on different risk factors, used different levels of health outcome measurement (workplace and individual) and conducted substantially different kinds of statistical analyses. Such a high level of heterogeneity required use of a synthesis approach most commonly associated with Slavin known as “Best evidence synthesis” (63).

Our best evidence synthesis was based on three aspects of the evidence on PE interventions affecting health outcomes: Quality, Quantity, and Consistency. Quality refers to the methodological strength of the studies as discussed above. Quantity refers to the number of studies that provide evidence on the same health outcome. Consistency refers to the similarity of results observed across the studies on the same health outcome.
Synthesis of the reviewed evidence on a particular PE intervention-health outcome relationship was ranked on a scale from strong evidence, through moderate, limited (partial) and mixed, down to insufficient evidence. Our guidelines were adapted from the best evidence guidelines used in the systematic review of workplace-based return to work interventions (25), themselves based on the review of prevention incentives of insurance and regulatory mechanisms for occupational health and safety (67). The specifics of our best evidence guidelines are found in Table M.5.
Application of these guidelines for each of the health outcome groupings was by consensus among the review team.

Table M.5 Participatory Ergonomics systematic review evidence synthesis guidelines

Strong evidence

Minimum quality: Very high

Minimum number of studies: 3 very high quality studies

Consistency: Very high quality studies all agree, and > 50% of high quality studies are consistent with very high quality studies.

Moderate evidence

Minimum quality: High

Minimum number of studies: 3 high quality studies

Consistency: 100% of high quality agree **OR** 66% of very high quality studies agree and > 50% of high studies are consistent with very high quality studies.

Limited (partial) evidence

Minimum quality: Medium

Minimum number of studies: 2

Consistency: Two studies converge on the same findings.

Mixed evidence

Minimum quality: Medium

Minimum number of studies: 2

Consistency: If there are two studies, they do not converge on the same findings. If more than two, relatively equal numbers of studies support and do not support effectiveness.

Inadequate evidence

No more than 1 at least moderate quality study (May be many more low quality studies)

M 6 Summary

After merging citations identified from the electronic search of the seven databases, removing duplicate citations, and including applicable studies from references lists the studies were reviewed for relevance. Following the review of titles and abstracts (and initial screening of full papers where necessary) those that met the relevance inclusion criteria and were appraised further for quality. Studies that were rated as medium quality or better using methodological strength criteria proceeded to data extraction. These studies formed the basis for our synthesis of evidence, though we were cognizant of all relevant studies when making our recommendations.

The steps of our review process, from the initial search strategy to evidence synthesis, are found in Figure M.6 below. The different reasons for exclusion in the steps outlined in Figure M.6 were documented and recorded. A copy of the papers which were selected for quality appraisal and/or for data extraction can be found in Appendix M.6.

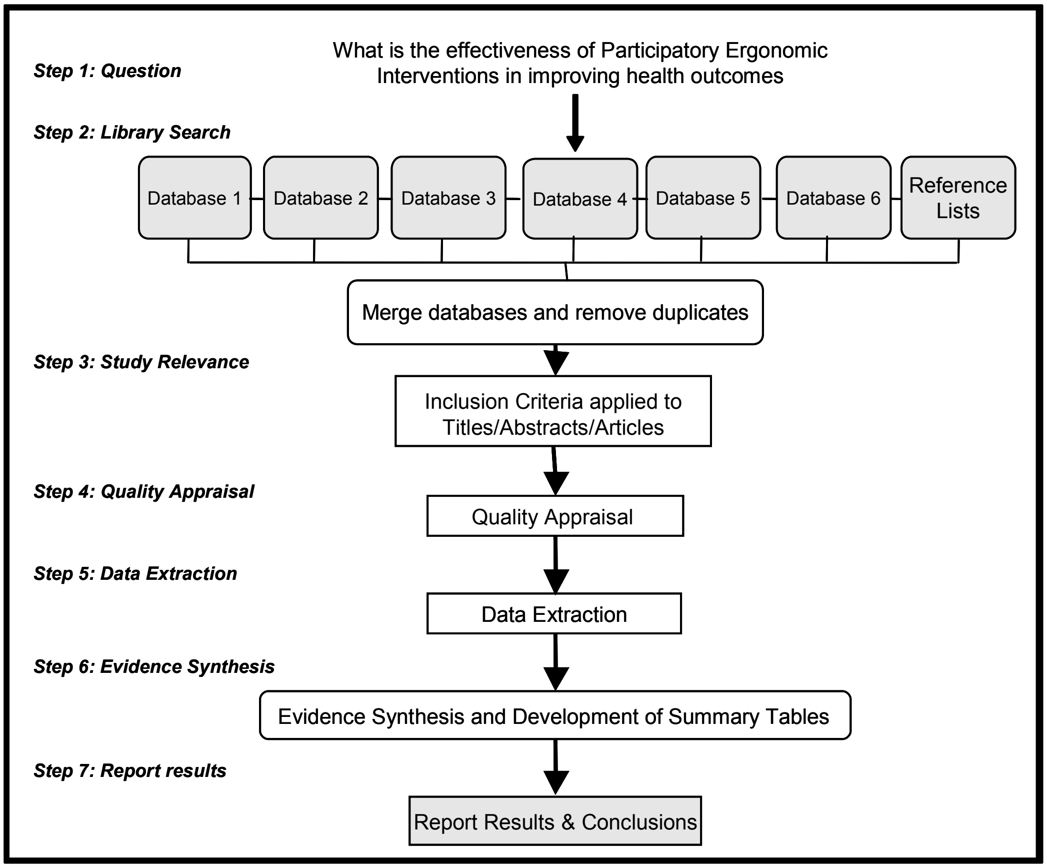

Figure M.6 Review process flowchart

Findings

F 1 Literature search results

Of the 442 non-duplicate retrieved citations, 23 studies met our relevance inclusion criteria and were assessed for methodological quality. Ten studies were rated as medium quality or better using methodological strength criteria and proceeded to data extraction. These ten studies formed the basis for our synthesis of evidence. A detailed breakdown of the flow of studies, including when studies were excluded, from the initial search strategy to evidence synthesis is found in Figure F.1 below.

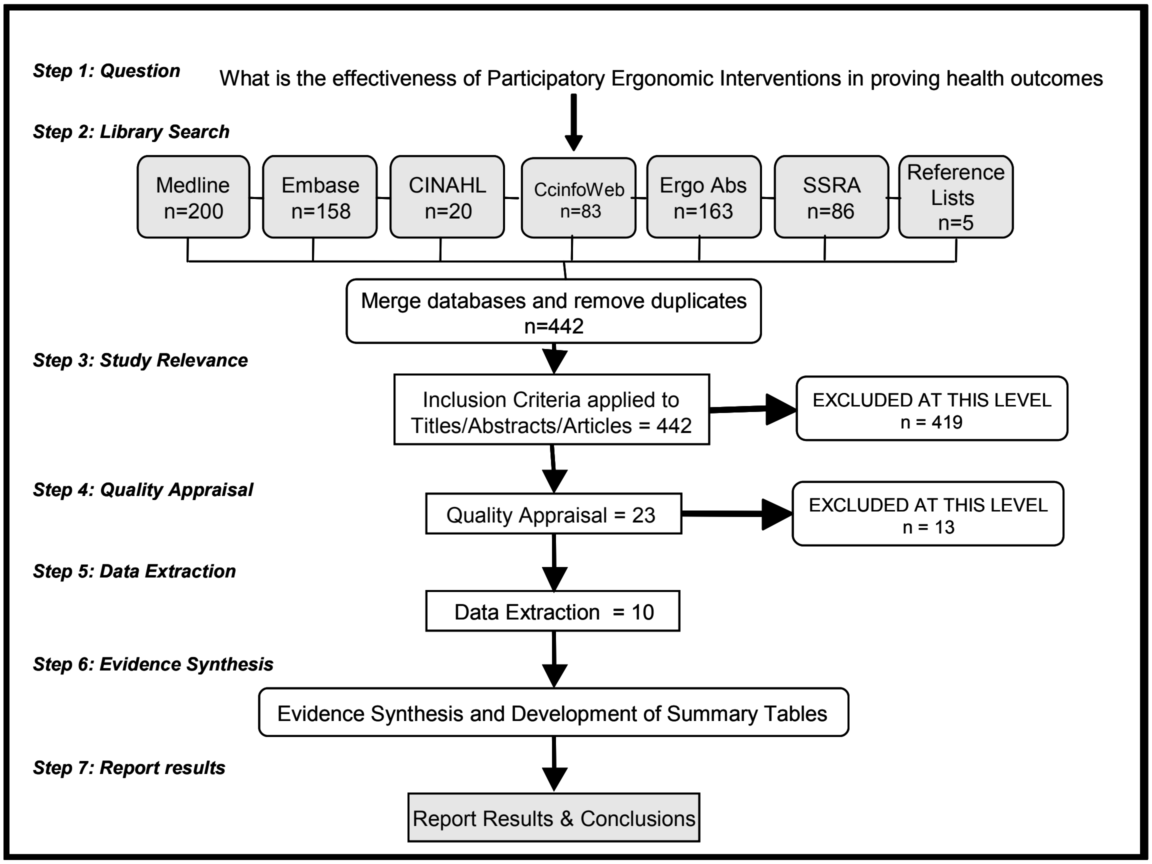

Figure F.1 Review process flowchart of studies at each step

F 2 Reasons for study exclusion

F 2.1 Study relevance There were different reasons for exclusion in the steps outlined in Figure F.1. Many (419 of 442 non duplicate studies) were not relevant to our research question. Although these studies often reported on interesting frameworks, experiences or aspects of ergonomics, they could not help us answer our *health evaluation* question of interest.

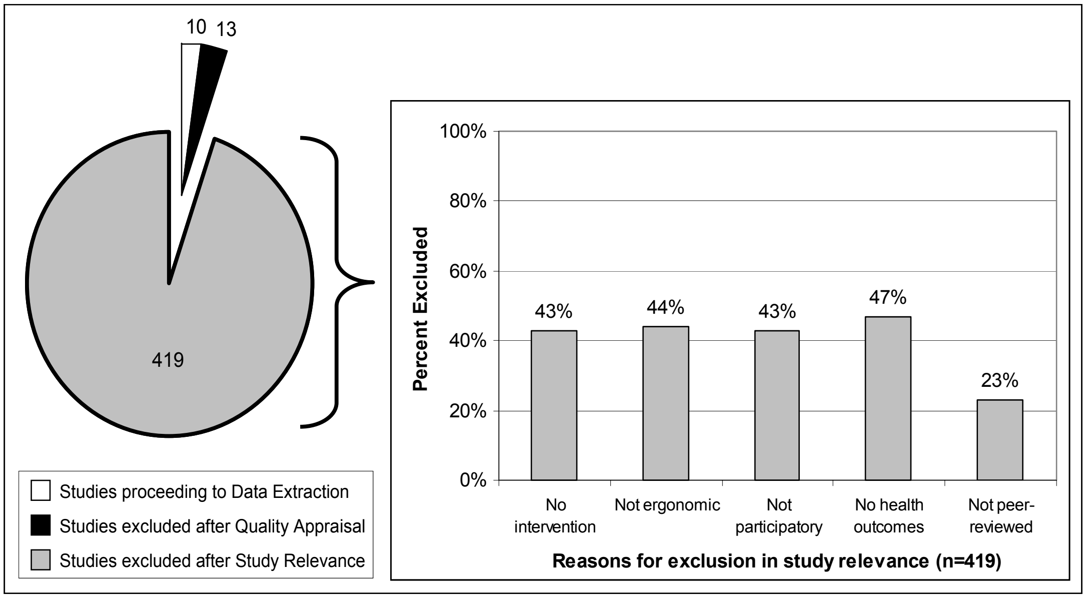

Figure F.2 Number of studies considered in literature review

F 2.2 Quality Similarly at the quality appraisal stage, many studies did not report on information important for assessing quality of *health evaluations.* These studies often provided important information about the process of participatory ergonomics. However our primary interest in *health evaluation*, with the concomitant criteria for methodological strength, was the primary reason for exclusion in the step from quality appraisal to data extraction. Hence the exclusion of studies in our review process does not necessarily suggest poor quality but rather reflects the number of studies addressing our specific research question.

F 3 Quality Appraisal

The 23 studies which met the study relevance criteria were assessed for methodological quality using our 27-item standardized quality appraisal form. As described in section M.3. *Quality Appraisal,* eleven of these questions were identified as being important to assess the internal validity of each study. These criteria were selected as the 'methodological strength'

(MS) criteria, and were used to determine which studies were of sufficient quality to proceed to data extraction.

Using these eleven criteria, studies were rated into four quality categories: very high (100% of MS criteria), high (75 – 99% of MS criteria), medium (45 – 74% of MS criteria) and low (≤ 44% of MS criteria). Studies rated as medium or higher were considered for data extraction. Of the 23 studies, 13 were rated as low and were not considered further in this review.

Ten studies were of sufficient quality to proceed to data extraction. Overall, one study was judged to be of very high quality, one of high quality, and eight of medium quality (see Table F.3). Profiles for these 10 studies can be found in Appendix F 3 (materials). For a listing of those studies that proceeded to quality appraisal and data extraction please refer to Appendix M.6.

Table F.3 Fulfillment of methodological strength (MS) criteria by DE studies in order of MS rating

First Author	# MS Criteria met by study	MS Rating
Ketola	11	Very High
Morken	10	High
Evanoff	8	Medium
Carrivick	7	Medium
Halpern	6	Medium
Lanoie	6	Medium
Reynolds	6	Medium
Wickström	6	Medium
Laitinen	5	Medium
Moore	5	Medium

In examining the methodological strengths and weaknesses of the state of evidence in PE interventions relevant to *health outcomes*, comparisons were made between DE studies (n=10), and Non-DE studies (n=13) on MS criteria. Not surprisingly, DE studies more commonly provided information relevant for our methodological strength criteria. However, there were some criteria in which all studies faired well and others in which both DE and Non-DE studies could improve. A summary of these comparisons appears below. More detailed comparisons on these quality criteria can be found in Appendix F.3 (F3 Figures and Table F 3).

The following MS criteria were **met frequently** by both DE and Non-DE studies:

- *Description of baseline characteristics at each level* – 100% of DE studies and 62% of Non-DE provided adequate information on baseline characteristics at the organization, department and worker level.

- *Changes resulting from the intervention documented* – 90% of DE studies and 70% of Non-DE studies reported on specific ergonomic changes that were either identified or implemented as a result of the PE intervention (see section F.4.2 for fuller description).

- *Health outcomes measured at baseline and follow-up* – 100% of DE studies measured health outcomes at both baseline and follow up. In regards to the Non-DE studies, 93% included baseline measures and 85 % had follow up measures.

- *Risk factors for musculoskeletal disorders measured* – 80% of DE studies vs. 63% of Non-DE studies measured risk factors for MSK disorders. However, this is an important difference, as intermediate outcomes or risk factors along the causal path are essential in understanding the effectiveness of PE in leading to changed health outcomes.

The following MS criteria were **met less frequently** by both DE and Non-DE studies:

- *Randomized allocation used* – Only 20% of DE studies and 0% of the Non-DE studies randomly allocated the intervention across equivalent groups. For the DE studies, allocation was at a group level for one study (Morken (49)), and at an individual level for one study (Ketola (36)).

- *Participation in intervention documented* – 30% of DE studies and 23% of Non-DE studies included documentation of participation. For DE studies, this criterion is elaborated on in section F4.1. Nevertheless, in many cases reviewers had difficulty ascertaining what proportion of those who might have participated actually did so.

    - *Co-interventions described* – 40% of DE studies vs. 23% of Non-DE studies addressed the issue of co-interventions in their report. Co-interventions considered in this literature included: workplace wide changes in production volumes or employee turnover, as well as specific additional components like clinical rehabilitation, e.g. physiotherapy, occupational therapy, or return to work activities.

- *Potential confounders measured* – 40% of DE studies vs. 0% of Non-DE studies measured confounders. Most confounders were considered at the individual level (i.e., seniority, age workload), as most workplace-level confounders were not tested for associations with the PE intervention and the health outcome. Lanoie (41) were the only investigators that included both levels.

- *Adjustment for relevant baseline differences* – 40% of DE studies vs. 0% of Non-DE studies adjusted for baseline differences, crucial in non-randomized designs.

The following MS criteria were **met frequently** by DE studies and **less frequently** by Non-DE studies.

- *Concurrent comparison groups used* – 70% of DE studies used comparison groups, while only 31 % of Non-DE studies used concurrent comparison groups. In this literature, comparison groups included: other similar workplaces, the rest of the workforce, similar groups of workers, and individually selected and randomized groups.

- *Appropriate statistical analyses conducted* – 90% of DE studies had appropriate statistical analyses, compared with only 15% of Non-DE studies. Among the DE studies, many made simple pre-post comparisons. Only 1 DE study (Laitinen (40)) completed descriptive analyses only for their health outcomes (although ANOVAs were done for intermediate variables). However, 62% Non-DE studies did not perform any statistical analyses.

Overall, the quality of PE intervention studies that assess health outcomes is quite low. Of the 23 relevant studies examining this question, 2 studies rated at high or very high on methodological quality. An additional eight studies were rated at ‘medium’, while 13 studies rated low in terms of their methodological quality.

There are several areas that studies of PE interventions could improve, including the documentation of participation level within the intervention, description of co-interventions and confounders, and adjustment for relevant baseline differences between groups. Random allocation procedures were also generally not used in these interventions. We recognize the challenge of doing so in complex interventions of existing groups (e.g., workplaces, departments). However, as noted above, techniques to minimize bias due to non-random sampling (e.g., adjustment for co-interventions, confounders, and baseline group differences) are also not well employed in these studies.

These weaknesses are particularly critical to workplace intervention research.

Despite the general weaknesses in methodological quality in this literature, there are several internal validity issues that studies seem to be addressing adequately, including: describing sample baseline characteristics, documenting ergonomic changes resulting from PE intervention, measuring health outcomes at baseline and follow-up, and measuring important MSD risk factors.

F 4 Data Extraction

There were ten studies that proceeded to the data extraction step. These ten DE studies came from a wide range of European and North American jurisdictions and occurred in a range of sectors. In this section, we describe our substantive findings on PE interventions in steps that parallel our conceptual framework set out in the Introduction (Figure I.2). We start with characterization of PE interventions and how they were structured (sub-section F.4.1), the kinds of changes that were identified and implemented (sub-section F.4.2.) and the information available (in these studies) on facilitators and barriers to the interventions (sub-section F.4.3). We then turn to documentation of risk factors and any changes in risk factors during the PE interventions (sub-section F.4.4), the health outcomes of interest (sub-section F.4.5), and the other outcomes that were included in the studies (sub-section F.4.6). See Appendix F.4, Tables F.4 a,b,c for detailed data extracted.

F 4.1 Characteristics of participatory ergonomics interventions

As indicated in the methods, the concept of participatory ergonomics (PE) was variously interpreted in the studies we reviewed. We chose to classify the characteristics of the PE interventions according to the participatory ergonomics framework (PEF) proposed and validated by Haines and colleagues (30). The PEF has nine dimensions with several nested categories and criteria to describe process and supporting characteristics of PE programs (see Table F.4.1 and below).

Table F.4.1 Number of DE studies described by each dimension and categories of the participatory ergonomic framework (PEF) (Haines et al., (30).

Dimensions	Categories	Criteria (taken from text and Table 6 of Haines et al, 2002)*	Number of studies†
Permanence	Ongoing	Ongoing participatory mechanisms … more integrated into the structure of the organization	5
	Temporary	Participatory ergonomics mechanisms functioning on a temporary basis	5
Involvement	Full Direct	Each employee participates directly in decisions about their work	2
	Direct Representative	Employee representatives are selected to represent viewpoints of a large number of workers	8
	Delegated	Representatives not actively representing the views of others but represent a typical subset of a larger group	2
Level of Influence	Group of Organizations	The PE process takes place across a number of organizations working or belonging to a group (such as a professional association)	1
	Entire Organization	The PE process takes place at a single organization or workplace	5
	Department/ Work Group	The PE process takes place in a department or workgroup within a single organization	10
Decision Making	Group Delegation	Management gives employees increased discretion and responsibility to organize … their jobs without reference back	2
	Group Consultation	The PE team is encouraged to make their views known on work-related matters but management retains the right to take action or not	7
	Individual Consultation	An individual worker is encouraged to make their views known on work-related matters but management retains the right to take action or not	2
Mix of	Operators	Workers involved in teams	10

Dimensions	Categories	Criteria (taken from text and Table 6 of Haines et al, 2002)*	Number of studies†
Participants	Line Management (Supervisors)	Managers/supervisors involved in teams	9
	Senior Management	Senior managers involved in teams	3
	Internal specialist/ Technical Staff	Internal specialist or technical staff (such as engineers, or health a safety specialists) involved in team	8
	Union	Union members or representatives involved in team	3
	External Advisor	External advisor (such as ergonomic consultant from outside of company) involved in team	7
	Supplier/Purchaser	Supplier or purchaser of equipment involved in team	0
	Cross-Industry Organization	Cross industry or organization personnel (such as industry association representative) involved in team	1
Requirement (for participation)	Compulsory	Participation required as part of job specifications	5
	Voluntary	Voluntary participation in PE process	5
Focus	Physical design/ Specification of Equipment/ Workstation/ Work tasks	Physical aspects of Equipment/ Workstation/ Work tasks were the focus of the intervention	10
	Design of Job Teams or Work Organization	Design of Job Teams or Work Organization were the focus of the intervention	6
	Formulation of Policies or Strategies	Formulation of Policies or Strategies was the focus of the intervention	1
Remit	Problems Identification	Involved in identification of problems	10
	Solution Development	Involved in generating solutions to problems identified	10
	Implementation of change	Involved in implementing change	10
	Set-up/ Structure Process	Involved in setting up or structuring the process	2

Dimensions	Categories	Criteria (taken from text and Table 6 of Haines et al, 2002)*	Number of studies†
	Monitor/ Oversee Process	Involved in monitoring or overseeing the process of the initiative	4
Role of Ergonomic Specialist	Initiates and Guides Process	Ergonomist is key in initiating and guiding process as integral part of duties	6
	Acts as Expert	Ergonomist is part of the team to provide expertise in ergonomic matters	8
	Trains Members	Ergonomist primarily focuses on training	7
	Available for Consultation	Ergonomist is available for consultation as needed (therefore may not be member of team)	8
	Not Involved	Ergonomist is not involved in the PE process	0

* There was some interpretation involved in determining the exact criteria for some of the categories because they were not explicitly defined in Haines et al. (30)
† Multiple responses to several categories are possible for some dimensions

Observations from applying the PEF framework to describe the PE interventions follow:

Permanence: half (5) of the studies reviewed had ongoing participatory ergonomics (PE) programs or processes, and half had temporary PE programs. However the permanence of the PE intervention was not always clearly indicated in the studies and those with ongoing programs reported permanence more clearly than those with temporary programs.

Involvement: eight studies had 'direct representative' involvement. This was likely the most common approach as 'delegated' (two studies) may not be perceived as participatory and 'full direct' (two studies) could be more difficult to implement, especially in larger workplaces.

Level of influence: all 10 studies reported that there was influence at the department level. Five studies reported having influence also at the level of the organization, while one study reported influence among a group of organizations. Departmental influence is likely more common as work at this level poses fewer implementation challenges than work with entire organizations or groups of organizations.

Decision making: seven studies had decision making power at a group consultative level, while two studies had decision making at a group delegation level. Two studies were also considered to have decision making at an individual consultation level i.e., a minority with individual workers having authority to make changes to their workstation or worktasks.

Mix of participants: all 10 studies reported some employee involvement in the PE process, a requirement for studies to not be excluded at the relevance stage. Nine reported supervisor involvement, eight had specialist/technical staff involved, and seven PE processes had an external advisor. Three studies reported union involvement and three studies reported senior management involvement. This mix of workplace and other actors with different interests, perspectives, skills and roles likely assists in mobilizing resources from within and outside an organization (see facilitators and barriers in Section F.4.3 below).

Requirement: It was often unclear whether participation in the PE process was completely voluntary for all participants at all times. Different team members may have been needed at different stages of the process e.g., ergonomic training may have been compulsory but involvement in a 'change' team more voluntary. Given the different disciplinary backgrounds of the researchers and practical, workplace nature of many of the interventions, informed written consent was not a usual procedure. Nonetheless, the review team thought that five studies had voluntary participation and five, compulsory participation.

Focus: in all 10 studies, workplace parties dealt with physical design or specification of equipment/workplace/work tasks (see section F.2 below for more on changes). Six also included design of job teams or work organization, while one formalized policies relevant to ergonomics. We recognize that the different levels of intervention focus may only represent part of what was actually carried out in the workplace or organization.

Remit: in all 10 studies, participants were involved in problem identification, solution development and implementation of change, consistent with a more ample notion of PE. In two studies PE teams were also responsible for setting up the PE structure or process, while in four team responsibility extended to monitoring/overseeing the PE process. Interestingly, the latter were more likely in 'ongoing' PE programs (versus temporary ones).

Role of ergonomist: in six studies an ergonomist (or individual with ergonomic responsibilities) was involved in initiating the PE process. Ergonomists also acted as experts (8 studies), consultants (10 studies) and team members (7 studies) i.e., they most commonly assumed multiple roles and likely multiple kinds of involvement.

There was substantial heterogeneity across studies particularly in the permanence of the PE process, requirement for participation and the role of the ergonomist. Some of this heterogeneity could have been due to differential reporting, as study authors did not set out to describe their PE interventions using the PEF. In fact, we extended our description of PE processes to include reports of ergonomic training and the duration of the PE intervention. Nine studies indicated that some ergonomic training was provided as part of the intervention (PE process). Seven indicated who provided training, in all cases the ergonomist (or person responsible for ergonomics). Eight clearly indicated who received the training: most often workers (8 of 9), supervisors in five, and only foremen and safety representatives in one (Wicktroem (73)).

As to content of the training, broad principles of ergonomics were conveyed in nine. Some also included assessment/identification of problems, problem solving approaches and solution implementation. The length of time spent in training varied greatly, from a single one hour session to 20 hours. In one case ongoing education was provided via notice boards (Wickström (73)).

The duration of the intervention was sometimes difficult to assess because of confusion with follow-up times post intervention or, in the case of ongoing programs, no fixed ending date. Nevertheless we found that durations varied from a matter of weeks (Reynolds (57), Ketola (36)) to 84 months or more (Moore (48)). Overall, six studies reported intervention durations of two years or more, perhaps reflecting the time required to implement sufficient changes with a PE process.

F 4.2 Changes Identified or Implemented

Turning to the types of changes reported, we found that the majority of studies identified (without implementation) or implemented (after identification) changes to the physical design of equipment and workplaces (see Table F.4.2). Fewer studies included changes in work tasks, job teams or work organization, the formulation of policies, or specific training. The focus on physical changes may be due to the traditional emphasis of ergonomics and workplace parties on the physical aspects of the work/worker interaction when concerned about MSD, despite the growing literature that indicates a role for psychosocial or work organization factors.

Table F.4.2 Types of changes identified and implemented *.

First Author	Physical design or Specification of:			Design of job teams and work organization	Creating Policies / Strategies	Training regarding specific techniques/ tasks†	Other
	Equip-ment	Work-places	Work tasks				
Carrivick	im	im	im		im	im	
Evanoff	id, im					im	id
Halpern	im	im		im			im
Ketola	id, im	im					
Laitinen	im	im					im
Lanoie	im	im		im			im
Moore	im	im	im	im			
Morken	im	im		im			
Reynolds	id, im	im					
Wickström						im	im

* id= identified im = implemented
†Not including general ergonomic training.

Many studies (6 of 10) reported changes that did not match the specific categories of Table F.4.2. These changes included:

- Creating a stretching and exercising program (Halpern (31)) or improving physical conditioning of workers (Wickström (73))
- Identifying improved maintenance procedures for existing equipment (Evanoff (22))
- Designing and implementing new rooms for rest-breaks (Laitinen (40))
- Working with a supplier to change the glue on existing packaging (Lanoie (41))

PE interventions can be expected to include a variety of changes that are not easily classifiable according to a set of generic categories. Such variety can be considered a strength of the PE approach, as the changes are directed to particular situations in particular workplaces with particular needs.

F 4.3 Facilitators and Barriers

Most studies made at least some reference to factors that either facilitated or hindered the PE process and implementation of identified changes. One of the most consistent findings was the importance of *active participation* and *acceptance* of the team members, particularly by the following actors: workers, senior and middle management, and union representatives (where applicable). This was an important hurdle that workplaces with an underlying “trust gap” or “scepticism” between management and labour had to deal with at the outset of the PE process.

The availability of an ergonomic expert, as either an active team member or an external advisor, was consistently reported as a benefit. These technical experts provided ergonomic training/education, assisted in identifying risk factors, and facilitated the team in problem identification and solution development strategies. Teams without such guidance and support noted that they were limited in their ability to adequately identify and remedy problems within the workplace. Nevertheless, one must be mindful that the interveners commonly co-authored the study reports, with only a few studies clearly separating the roles of intervener and evaluator. Therefore, a basis for potential bias exists towards finding a benefit in expert involvement and, further, reporting on positive experiences (but not the negative or null ones). On the one hand, we admire those interveners who subjected their work to formal evaluation and encourage such openness to scrutiny. On the other hand we worry that interveners may overplay benefits, primarily because of their belief in intervention efficacy and desire to promote beneficial interventions, though financial interests have also been found important for health care interventions).

Access to adequate resources was also a commonly identified factor. Provision of ‘protected’ time for members to participate in team meetings, financial investment in the process, and availability of workplace structures for accessing information regarding risk factors, equipment specifications, and personnel were key facilitators of the PE process. Conversely, constraints on resources were significant barriers to adequate implementation in some studies.

Instability within the workplace e.g., employee turnover, downsizing, or more globally at the industry level e.g., economic recession, at the time of the PE intervention was found to hinder the PE process – affecting both workers’ confidence in and the everyday implementation of the participatory ergonomic process.

F 4.4 Risk Factors Considered
Identification and assessment of risk factors were suggested as integral parts of the PE process in most of the DE studies, in keeping with our conceptual framework for PE (see Figure I.2 in Introduction). Table F.4.4 shows the variety of risk factors and, when reported, the changes observed during the course of the study.

Table F.4.4 Summary of risk factors considered and changes recorded for those risk factors (if reported).

First Author	Risk Factors / Intermediate Variables Considered	Change in Risk Factors*
Carrivick	Risk factors checklist used to assess: - actions and movements - workplace and workstation layout - working posture and position - duration and frequency of manual handling - location and distance of loads moved - weight and forces - characteristics of loads and equipment - work organization - work environment - skills and experience - age and clothing	Not reported
Evanoff	1) Job satisfaction 2) Psychosocial stressors 3) Social support among co-workers (work APGAR)	Improvements in 1) job satisfaction ($p<0.01$), 2) perceived psychosocial stressors ($p<0.01$), and 3) social support among co-workers ($p<0.05$) associated with decreases in proportion of workers reporting symptoms.
Halpern	Hazard intervention and abatement strategies identified: - Posture, - Forces, - Repetitions, such as: excessive reaching, twisting and bending, forceful pinching and gripping, awkward hand postures when cutting	Although changes to workstations, tools, process flow and employee exercise/stretching were described which indicated that posture and force were improved, specific changes to the risk factors identified were not reported in this study.

First Author	Risk Factors / Intermediate Variables Considered	Change in Risk Factors*
Ketola	1) Workstation settings 2) Ergonomic rating (video analysis - scale 4-10, 10 is better)	1) Changes in screen height, keyboard height and acquisition of accessories occurred more often in the intensive group. Adjustments to chair or mouse location occurred in all groups. 2) Mean ergonomic ratings significantly higher in the intensive group than in the education or reference group at 2 and 10 months follow ups, but not at baseline.
Laitinen	1) housekeeping standards 2) perceived physical changes 3) perceived psychosocial changes	1) Housekeeping index increased from 57% to 89% ($p<0.001$); 2 & 3) physical working conditions and psychosocial work environment both significantly improved when considered for all responses ($p < 0.001$ and $p < 0.02$ respectively). All other aggregated Time 1 (Q1) findings not significant; 2) Perception of physical working conditions improved in all departments: order and tidiness ($p<0.001$), pleasantness of work environment ($p<0.05$), layout of work stations ($p<0.05$), safety of working methods ($p<0.05$). 3) Psychosocial environment improved in three departments ($p<0.05$); For Time 2 (Q2) two of 11 groups of questions showed statistical improvements: communication and cooperation (p level not given) - other 9 groups showed no significant difference; For specific Q2 questions - total responses: Company goals are known ($p<0.01$), Practical places for tools ($p<0.01$), workstation is clean and in good order ($p<0.05$). In Dept. H: positive prospects in work, practical tools are available ($p<0.05$); practical places for tools, workstation is clean and in good order, regular feedback of outcome, visual appearance of work station is pleasant ($p<0.01$); Company goals are known ($p<0.001$); In Dept. J: daylight in workstation, company goals are known ($p<0.05$); workstation is clean and in good order ($p<0.01$);

First Author	Risk Factors / Intermediate Variables Considered	Change in Risk Factors*
Lanoie	1) Muscular use 2) asymmetric postures 3) lumbar strain in biomechanical laboratory 4) physiologic demand measures	1) muscular use decreased in manual handling of boxes from 80% of maximal capacity to 40% of maximal capacity 3) biomechanical analysis in laboratory found a decrease in low back muscle use by 15.7% with new glue used 4) significant reduction in physiologic demand with new handling equipment
Moore	1) worker safety survey 2) CTD risk factor checklist 3) worker feedback 4) strain index	2) significant reduction in percentage of MSK risk factors found (no statistical significance) One of the articles that represent this study indicated detailed changes in risk factors for individual job changes based on the risk factor checklists and strain index tool. These changes were not statistically analyzed but were mostly positive.
Morken	1)Coping strategies 2) Job demands, Job control and Social support	1) coping strategies: intervention groups used more strategies then control groups (p=0.043, ANOVA). Intervention group 2 increased most (mean change=0.041, 95% CI 0.005, 0.077). Control group B declined by 0.010, 95% CI -0.02, 0.001). Intervention group 2 and control group B differed (p=0.017) and Intervention group 2 and control group A differed at borderline significance (p=0.068). The largest increase in intervention group2 was for following: "work on other tasks that are less strenuous", "use equipment to reduce physical strain" & "ask colleagues for help with strenuous work tasks". 2) job demands, control and social support: social support in intervention group 2 improved slightly from pre to post. All other groups tended to decline (p=0.10, ANOVA). Job demands and control did not differ significantly.

First Author	Risk Factors / Intermediate Variables Considered	Change in Risk Factors*
Reynolds	1) CTD task analysis using manual methods 2) acquiring biomechanical data on posture, force, repetition, 3) calculating daily exposure scores for wrists (DWE), neck/back, shoulders, and legs (DE). DWE = (grip force + postural deviations) x frequency DE = postural deviations x frequency	Case study presented results on: 3) DWE which showed a reduction in daily wrist exposures comparing 'before' to 'after' (before R wrist: 30,927 to after R wrist: ~10,500; before L wrist: 16,653 to after L wrist: ~14,000) ~14,000) and DE which also showed a reduction comparing 'before' to 'after' (shoulders before: 47,580 to shoulders after: ~23,000; and Neck/back before: 41,236 to neck/back after: ~19,500) Other risk factor measures were not presented.
Wickström	1) biomechanical load (reported as occurrence of low back pain, which is a health outcome measure) 2) ergonomic ways of working 3) physical exam (fitness of back tissues)	2) ergonomic ways of working: - adhering to ergo principles at work (white collar: chisq(2)=2.17, p=0.34; blue collar: chisq(2)=9.64, p=0.008) - use of mech equip to avoid excessive postures blue collar: chisq(2)= 17.28, p=0.001); no white collar exposure - physical exercise no changes (white collar: chisq(2)=4.83, p=0.089; blue collar: chisq(2)=1.054, p=0.59) 3) fitness of back tissues: - performance of abdominal muscles better among white collar than blue collar (no stats provided) - no changes observed in mobility of spine of performance of abdominal muscles in either group - blue collar endurance time of back muscles increased (F(2,128)=3.99, p=0.021)

* refer to Appendix Tables F.4a, b, c for fuller version of the data extracted.

The rigor used to measure risk factors and explicitness in reporting these factors varied considerably across the studies. Several studies only conducted risk factor assessment as part of the initial hazard identification step in the PE process. Those reported reflected the particular nature of the work operation or job. In other studies, the risk factors were measured using explicit standardized tools, considered intermediate variables, and analyzed statistically for change over the course of the intervention. The latter approach considerably aids interpretation of changes or lack of changes in health outcomes.

F 4.5 Health Outcomes

We grouped the wide variety of health outcome measures in the DE studies (refer to Appendix Table F 4b) into three main groupings:
1) symptoms of musculoskeletal pain and/or discomfort, most often from questionnaire; 2) injury records in-plant or lost time claims for workers' compensation; and 3) sick leave in general or lost workdays specifically due to MSD (see Table F 4.5 below). Symptoms (5 studies) and injuries (6 studies) were more common, likely in keeping with their greater frequency (prevalence for symptoms and incidence for injuries) and greater sensitivity to change during the course of a PE intervention. Three studies had more than one health outcome: Evanoff (24) and Reynolds (57) measured both symptoms and injury data and Wickström (73) included measures of both symptoms and sick leave.

Table F.4.5 Summary of Health Outcomes Measured and Results Obtained

First Author	MSK Symptoms (1)	Injury Records/ Claims (2)	Sick Leave/ Lost Workdays (3)	Results (for health outcomes only)
Carrivick		•		Positive
Evanoff	•	•		Positive
Halpern		•		Positive
Ketola	•			Positive
Laitinen			•	Positive
Lanoie		•		Positive
Moore		•		Positive
Morken	•			No Change
Reynolds	•	•		Positive
Wickström	•		•	Positive
Total # of Studies	**5**	**6**	**2**	

We also attempted to estimate effect sizes for 1) odds ratios and rate ratios according to guidelines devised for this review (see Appendix Table F.4.5). and 2) means, proportions, chi-square and regression estimates using Cohen's approach (14).

Outcome 1: MSK symptoms: Among the five DE studies that measured musculoskeletal symptoms (Evanoff (24), Ketola (36), Morken (49), Reynolds (57), Wickström (67)), various questionnaire instruments were used that captured different attributes of MSK symptoms. These attributes included the frequency or severity of symptoms overall, the intensity of pain, and the location of symptoms by body region e.g., low back pain occurrence in the past year. Four of the five DE studies found a reduction in MSK symptoms with the PE intervention. Morken (49), however, found that change in MSK symptoms did not differ significantly between intervention and control groups. Effect size could only be estimated in the Ketola (36), study, and it was small.

Outcome 2: Injury Records or Claims. Six DE studies sought to determine the effect of a PE intervention on the number of injuries, as measured by plant injury records (i.e. OSHA 200 logs in the US based studies), claims, , or equivalent measures as obtained from administrative database sources. All studies reported reductions in injury rates to varying extents. For example, one of the biggest improvements was shown in the study by Halpern (31), where the intervention group had an 85% reduction in the total number of claims, compared to the reference group which experienced an increase in the number of claims. The PE intervention reported by Carrivick (12) also showed a large effect, with an odds ratio for lost time injury frequency post intervention of 0.353 compared to the referent group (significantly different from zero). In general, the large effect sizes occurred with cruder analyses as in Halpern above. The small effect sizes were found in more sophisticated analyses which took into account population characteristics and co-interventions i.e. Lanoie (41).

Outcome 3: Sick leave/lost workdays. Both studies using this type of health outcome extracted from administrative data bases reported improvements. Specifically, Laitinen (40) demonstrated that following a PE intervention absenteeism went from 12.8% to 9.9% in the affected workforce. In the study by Wickström (73), sick leave decreased from an average of 3.1 days lost due to low back disorders before the PE intervention to 1.9 days lost after the PE intervention. Formal effect size estimates could not be estimated for either of these, however.

F 4.6 Other Outcomes Some studies included findings on outcomes that were not of primary interest for this review. They were included in the data extraction tables to capture any other potential changes resulting from the PE interventions (see Appendix Table F.4c). A number of studies that reported on workers' compensation claim data, also included the monetary valuation of these health outcomes as compensation costs or the like, which most often were towards reduced costs to the workplace e.g., Evanoff (24), Halpern (31), Moore (48). In addition, using a simple productivity measure Reynolds (57) was able to demonstrate improvements with the PE intervention.

F 5 Evidence Synthesis

Among DE studies, the PE intervention always included multiple activities at several levels of the organization (Section F 5.1). Across the studies, the mix of ergonomic changes made by the PE teams varied substantially (Section F 5.2) as did the risk factor changes found (Section F 5.4). All but one of the DE studies showed positive health outcomes (Section F 5.5) but effect sizes could only be estimated for a small number of the outcomes. The large variety in PE characteristics, ergonomic changes and changes in risk factors and the small number in which we could estimate health outcome effect sizes meant that we could not analyse the role of the former in determining variation in the latter, as hoped for in our initial conceptual framework for PE intervention evaluation (Fig I.2).

We could, however, synthesize the evidence for each health outcome.

F 5.1 What is the impact of workplace PE interventions on musculoskeletal pain & discomfort?

One very high quality study (Ketola (36)) was positive and showed small effects; one high quality study (Morken (49)) found little change; and three medium studies (Evanoff (24); Reynolds (57); Wickström (70)) found improvements in MSK symptoms, though the effect sizes could not be estimated.

Taken together, using a best evidence synthesis approach, the current studies provide **limited (partial) evidence** that PE interventions can have a small, positive impact on MSK symptoms.

F 5.2 What is the impact of workplace PE interventions on injuries and workers' compensation claims?

Six medium quality studies (Carrivick (12); Evanoff (24); Halpern (31); Lanoie (41); Moore (48); Reynolds (57)) all showed reductions in lost time injuries or claims, particularly for MSK conditions e.g., low back pain. Effect sizes ranged from large in the cruder analyses to small in the more sophisticated analyses that took into account employee population changes and co-interventions.

Taken together, using a best evidence synthesis approach, the current studies provide **limited (partial) evidence** that PE interventions can have a positive impact in reducing injuries and workers' compensation claims. The size of this impact may range from small to large and requires clearer characterization in future research.

F 5.3 What is the impact of workplace PE interventions on lost workdays and sickness absence?

Two medium quality studies showing positive results were found (Laintinen (40); Wickström (73)) but effect sizes could not be estimated from either.

Taken together, using a best evidence synthesis approach, the current studies provide **limited (partial) evidence** that PE interventions have a positive impact on lost days from work or sickness absence, but the magnitude of the effect requires more precise definition.

F 6 Conclusions

Nine out of ten studies of medium quality or better reported a positive effect on health outcomes associated with PE. However, the heterogeneity in research methods and reporting across the studies led the review team to assign an appraisal of 'limited (partial) evidence' that PE interventions are effective in improving health outcomes. Specifically, our findings can be summarized as follows:

- There is **limited (partial) evidence** that PE interventions have a positive impact on **MSK symptoms.**
- There is **limited (partial) evidence** that PE interventions have a positive impact on **injuries and workers' compensation claims**.
- There is **limited (partial) evidence** that PE interventions have a positive impact on **sickness absence or lost days from work.**

F 6.1 Strengths of conducting a systematic review

The volume of studies published is more than most practitioners or researchers can easily keep track of or synthesize. This is confirmed for participatory ergonomics by the number of studies shown in Figure I.1 in the Introduction. Systematic reviews are useful tools for researchers, practitioners, workplaces, and policy makers to remain current with the evidence.

A systematic review differs from a narrative review written by a content expert in a relevant field because it is designed to be transparent and reproducible in the judgements made. In following an explicit process of scrutinizing, tabulating, and integrating all relevant studies that address a specific research question, a systematic review aims to eliminate bias in the selection and synthesis of evidence. It strives to produce an objective appraisal that can enable practitioners and researchers to resolve uncertainty when original studies and editorials disagree on the conclusions to be drawn from the evidence for a particular research question. In many cases, a systematic review can demonstrate gaps in the quality of evidence for a question and thereby identify areas for further research and evaluation.

F 6.2 Limitations of this systematic review The evidence considered was from peer-reviewed literature which could be identified through the search of the seven electronic databases and scanning of reference lists from selected studies. It is possible that a broader search of the grey literature, conference proceedings, and dissertations might have yielded further relevant evidence on the effectiveness of PE interventions on health outcomes.

Time and resource availability limited the range of research questions on PE interventions considered in this review, leaving other pertinent questions such as determining the most effective process for conducting PE interventions, measuring risk factors/exposures, ensuring adequate participation, or maintaining interest to ensure sustainability to other reviews.

F 6.3 Strengths of this systematic review Our search for evidence confirmed that this is the first systematic review to focus on the effectiveness of PE interventions in improving health outcomes **(see Figure I.2**). Our review has advanced the methodology for appraising study quality within this body of literature to include a wider spectrum of study designs than is typically considered in most systematic reviews. We actively engaged the participation of stakeholders in the genesis and conduct of this review. Such early involvement was important to ensure our research question responded to our stakeholders' needs and interests. Further, including a stakeholder in conducting the review was a means to build capacity in utilization of research findings.

Recommendations

After the critical scrutiny that is involved in conducting a systematic review, it is tempting to only recommend that more and better research is needed. Nevertheless, the generally positive findings that we uncovered provide us enough assurance to recommend continued implementation of PE interventions (R.1.), in parallel with improved evaluation research on the impacts of PE interventions on health outcomes (R.2), and consideration of systematic reviews on other kinds of evaluations of PE (R.3).

R 1 Implementing PE interventions to reduce MSD burden
Given the evidence linking workplace exposures to the burden of MSD in working populations (52) we should continue to practice methods proven to reduce the burden. Some might suggest that our review did not uncover sufficiently strong evidence to endorse PE interventions. However, others have argued for different standards of evidence for *preventive* interventions like PE which reduce exposure to hazards (26). The review team agrees with this perspective and recognizes the struggles faced by workplace parties and policy makers in finding effective interventions to reduce the unacceptable burden of MSD among working Canadians. Hence our first recommendation that:

PE interventions continue to be implemented in workplaces as one means of reducing MSD burden among Canadian workers (R.1)

R 2 Evaluating PE interventions for improved MSK health
Our systematic review points to the need for researcher/evaluators to accompany workplace parties in their efforts to evaluate the impact of PE interventions along with ergonomists and other technical experts. In doing so, we have a set of recommendations that are directed both at researcher/evaluators and workplace/ergonomist interveners. Note that we suggest a separation of these roles, in keeping with the need to reduce the perception of bias as much as any possibility of actual bias in the results of an evaluation of a PE intervention.

Drawing particularly on the findings pertaining to methodological criteria, we propose the following recommendations to improve the quality of research and evaluation of PE intervention impacts on MSK health:

R 2.1 Evaluation study designs. Many PE interventions are initiated by enthusiastic workplace parties or skilled ergonomists who are fundamentally engaged volunteers. Hence the notion of randomization of interventions appears foreign to the very principle of participation. While recognizing this tension, when opportunities arise at the multiple organization or multiple site level to sequentially initiate PE processes, randomization of initiation should be considered e.g., as Straker and colleagues did in conjunction with labour inspectors. Organizations may find this appealing because they can sequentially apply limited resources to making changes, leaving some sites to act as time-based referents (often called controls). Robson and colleagues (59) have argued strongly for the greater study validity that can be achieved by such designs. Others have argued at a minimum for the use of concurrent comparison groups (16), as was creatively achieved by a number of the studies included in this systematic review. Hence our first evaluation research recommendation is that:

Concurrent comparison or referent groups be used in PE evaluations whenever possible, including consideration of randomization of interventions when many sites or organizations are involved ***(R 2.1).***

R 2.2 Source population and sampling frame. Many of the studies that we assessed for quality lacked sufficient information regarding the source population and sampling frame. In some instances, this reflects an oversight on the part of the researchers or a lack of appreciation of its importance (15). As well, part of the explanation lies in the fact that many studies used administrative data as their primary source of outcome measures. Consequently their unit of analysis was the department or workplace, but there remained inadequate descriptions of the other work groups or departments that made up the larger whole used for comparison purposes. Different units of analyses such as workers, workplaces, wards, and supervisors, reflect the fact that interventions can be aimed at different levels of action (16). Hence our second evaluation research recommendations is that:

*Greater efforts should be made to document and describe the source population(s). (**R 2.2**)*

R 2.3 Level and Intensity of Participation. Participation in PE was interpreted and applied differently in different studies, which we documented with the help of the extensive PE framework (PEF) devised by Haines et al. (30). Yet a considerable lack of consistency was noted in reporting on the various dimensions of the framework, partly because of the use of different frameworks, or partly because no overarching theory of change was used for many interventions. As in most interventions, intensity and coverage are important. For PE this must be partly measured by the kind and extent of participation in PE implementation. Although the research methods to achieve such documentation should partly be qualitative (see R.3. below) quantitative measures are also important. Hence, we recommend that:

*Those utilizing PE approaches should formally document the level of participation within the organization, the extent of involvement, and the coverage or proportion of those involved in order to provide much needed measures of PE intensity (**R 2.3**).*

R 2.4 Specific Ergonomic Changes. In our review, we included an extensive summary table of the types of ergonomic changes that were identified and/or implemented in each of the studies. Such documentation is key to permit adequate explanation for the reasons for changes in risk factors and eventually health outcomes (as per Figure I.2). Hence we recommend that:

Ergonomic changes be documented in as much detail as possible, to help describe intervention intensity and type, and to aid the applicability of the research or evaluation findings to other workplace settings ***(R 2.4)****.* .

R 2.5 Changes in Risk Factors/Exposures. Given the growing understanding of the contribution of physical and organizational risk factors in the causation of MSK disorders, intervention studies need to document changes in these risk factors to bolster explanation of a PE interventions' effectiveness. As per Figure I.2, changes in exposures are important intermediate variables on the path to changes in health outcomes. We therefore strongly recommend that:

PE evaluations should delineate the various risk factors measured and their links to health outcomes should be explicitly analyzed ***(R 2.5)****.* .

R 2.6 Co-interventions. If major changes in the workplace, reorganizations, or other interventions, aside from the intended PE intervention under investigation, have taken place during the study period, changes in health outcomes may be hard to attribute to the PE intervention alone. As co-interventions were particularly poorly addressed in the studies in this review, except for Lanoie and colleagues evaluation in Quebec (41), we recommend that:

Future evaluation research pay particular attention to ways of explicitly describing co-interventions and dealing with their impacts in the analyses. ***(R 2.6)****.*

R 2.7 Confounders. Individual confounders such as demographic factors and co-morbidities can differ greatly between groups in a study and departmental confounders such as grievance rates may also vary across groups. By definition, confounders are related to both the PE intervention and to the health outcome, making attribution of changes in health outcomes to the PE intervention along difficult. Few of the studies that the review team appraised for quality adequately dealt with confounders. Hence, we recommend that:

Potential confounders at different workplace levels be clearly described and adjustment for their effects carried out if required. ***(R 2.7)***

R 3 Conducting complementary systematic reviews
When considering the process of PE, workplace context is of considerable importance in potentially facilitating or hindering the success of a PE intervention. Previous studies have identified such factors as the organization's commitment to change, the existing organizational climate, and resources as especially significant (12; 40). Despite their utility for practitioners, not all studies consistently reported on such issues. Moreover, a mention of facilitators and/or barriers of the intervention was usually very brief in the DE studies. Although we might argue for greater information on these aspects in the studies reviewed, we are aware that we did not include a number of studies that do in fact examine context and the facilitators and barriers to PE interventions. Such a focus is more in keeping with the *process evaluation* literature and could be extremely useful to PE practitioners, workplace parties and policy makers. Hence, we recommend that:

A systematic review of PE process evaluations be undertaken by a team including qualitative researchers ***(R 3.1***).

We understand the need for greater information relevant to the "business case" for ergonomics and the parallel inclusion of both productivity outcomes and health outcomes in research on PE interventions (21). On the other hand, we know that the number of economic evaluations and their quality is likely limited at the present time. Hence, we recommend that:

PE interventions be included in systematic reviews of economic evaluations of workplace interventions to reduce the burden of MSD **(R 3.2).**

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