Scand J Work Environ Health 2005;31 suppl 2:75–87

Effectiveness of measures and implementation strategies in reducing physical work demands due to manual handling at work

by Henk F van der Molen, PhD,[1, 2] Judith K Sluiter, PhD,[1] Carel TJ Hulshof, PhD,[1] Peter Vink, PhD,[3] Monique HW Frings-Dresen, PhD[1]

van der Molen HF, Sluiter JK, Hulshof CTJ, Vink P, Frings-Dresen MHW. Effectiveness of measures and implementation strategies in reducing physical work demands due to manual handling at work. *Scand J Work Environ Health* 2005;31 suppl 2:75–87.

This review aimed at producing insight into the effectiveness of interventions to reduce the physical work demands associated with manual (materials) handling in the work situation and musculoskeletal symptoms in the longer term. A systematic electronic literature search between 1990 and February 2003 was performed in the following databases: Embase, Medline, HSE-line, Nioshtic, and Nioshtic-2. Three inclusion criteria were applied, and altogether 44 studies were included for review. The interventions were divided into two categories, (ergonomic) measures and implementation strategies. One randomized controlled field study was found that established a causal effect for a combination of implementation strategies in reducing the physical work demands associated with manual handling and reducing acute musculoskeletal symptoms. All four of the controlled field studies showed a significant reduction in the physical work demands when lifting devices were part of the intervention. Two of these studies measured a significant reduction in low-back disorders in the longer term. Several uncontrolled pre-post studies showed effects in the same direction. Of the 26 implementation strategies, 21 that measured an improvement in the process variables (eg, aimed behavioral variables) used a participatory ergonomics approach, an education (or training) program or both with the direct involvement of workers. It was concluded that significant reductions in physical work demands and musculoskeletal symptoms were found when (mechanical) lifting devices were part of the intervention. The higher quality studies that showed improvement in behavior indicate the importance of using facilitating and educational strategies in the implementation of ergonomic measures.

Key terms implementation; intervention; manual (materials) handling; musculoskeletal symptoms; systematic review; strategies; work.

As in the construction industry and health care, many industrial work situations involve the manual handling of materials (1). The manual handling of construction materials involves considerable physical work demands (2, 3) and is considered to be high risk for the development or exacerbation of musculoskeletal symptoms. In health care the manual handling of patients is also associated with high physical work demands and musculoskeletal disorders (4–6). In addition, various reviews have shown a relationship between manual (materials) handling and musculoskeletal disorders in both industrial and health care settings (7, 8).

Since it is assumed that lifting, carrying, pushing, and pulling at work increase the risk of musculoskeletal symptoms, the implementation of mechanical aids to reduce physical work demands in heavy work is a well-known approach for reducing this risk (9). However, there is little evidence of the effectiveness of (ergonomic) measures in daily practice on musculoskeletal symptoms (5, 8). Furthermore, information about the effectiveness of implementation strategies with respect to physical work demands and musculoskeletal symptoms is even scarcer.

This study makes a distinction between the effectiveness of (ergonomic) measures to reduce physical

1 Academic Medical Center, University of Amsterdam (Department: Coronel Institute for Occupational and Environmental Health, Research Institute AmCOGG), Amsterdam, The Netherlands.
2 Arbouw, Amsterdam, The Netherlands.
3 Technical University Delft / Industrial Design, Delft, The Netherlands.

Reprint requests to: Dr HF van der Molen, Academic Medical Center, Universiteit van Amsterdam, Coronel Institute for Occupational and Environmental Health, Research Institute AmCOGG, Meibergdreef 9, 1105 AZ Amsterdam, The Netherlands. [E-mail: h.f.vandermolen@amc.uva.nl]

work demands and, ultimately, musculoskeletal symptoms and the effectiveness of the various strategies to implement these measures in daily work practice (figure 1). Measures can be defined as (ergonomic) controls to eliminate or reduce the physical work demands associated with manual handling. Implementation strategies, however, involve the planning and processing of the implementation of (assumed) effective measures aimed at incorporating them in the job, the work organization, and the sector of industry (modified according to the definition in reference 10). With an implementation strategy as an independent variable in an intervention study, process variables become important as intermediate measures. An awareness of possible risk factors, changing attitude towards risk factors, and actually changing behavior, such as, for instance, starting the use of mechanical aids, are examples of intermediate process variables. In implementation studies there are, according to van der Molen et al (11), seven phases involved in changing behavior with respect to (ergonomic) measures for every actor involved in the implementation process (eg, the phase of "being aware of the measures" or the phase of "wanting the measures"). On every level, an obstacle can arise that results in an actor not proceeding with the implementation process.

National institutes of safety and health (eg, the National Institute for Occupational Safety and Health in the United States, Workforce in Australia, and the Health and Safety Executive in England) have advocated the use of preventive strategies to reduce the biomechanical workload in association with manual handling in interventions at work in order to reduce the incidence and prevalence of musculoskeletal disorders (12–14). This overall preventive strategy assumes a dose–effect relationship between the mechanical workload associated with manual handling and musculoskeletal symptoms. In addition, this preventive strategy emphasizes mechanical workload as the causal factor for musculoskeletal symptoms. Therefore, if the mechanical workload due to manual handling is an important determinant of the development of musculoskeletal symptoms in the longer run, interventions aimed at reducing physical work demands should be evaluated. Westgaard & Winkel (15) reviewed the effectiveness of various ergonomic interventions in the workplace with respect to internal mechanical exposure, acute responses, and health effects as dependent variables. The objective of the present systematic review of the literature was to produce insight into the effectiveness of (ergonomic) measures and implementation strategies aimed at reducing the external mechanical exposure (physical work demands) associated with manual (materials) handling in work situations, and eventually at reducing musculoskeletal symptoms. Physical work demands and musculoskeletal symptoms are used as dependent variables to assess the effectiveness of the interventions in the workplace because practical changes in the workplace aim at changing the external exposure (16). Moreover, this review includes studies measuring (intermediate) process variables to assess the different phases of implementation strategies to reduce physical work demands associated with manual handling at work.

The objective of the review can be operationalized into three different questions (figure 1), one regarding the effectiveness of (ergonomic) measures (i), and two on the effectiveness of implementation strategies (questions ii and iii): (i) What is the effectiveness of (ergonomic) measures in work situations with respect to reducing the physical work demands associated with manual handling and eventually reducing musculoskeletal symptoms?, (ii) What is the effectiveness of implementation strategies in work situations aimed at reducing the physical work demands associated with manual materials handling on (intermediate) process measures?, and (iii) What is the effectiveness of implementation strategies in work situations with respect to reducing the physical work demands associated with manual handling and eventually reducing musculoskeletal symptoms?

Methods

The studies were retrieved through a search in the following literature databases: Medline (1990-February 2003), Embase (1990-February 2003), HSE-line (1990-January 2003), and Nioshtic (1990-January 2003). A sensitive literature search combined the following three groups of free text words in the title and the abstract: "intervention" or "implementation" or "effect study" or

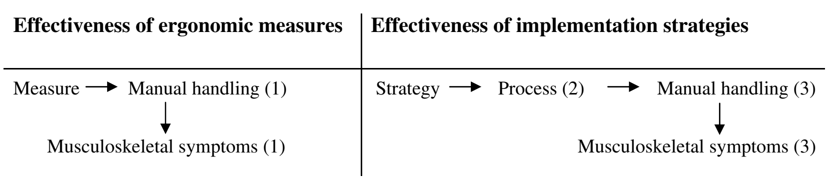

Figure 1. Scheme for the evaluation of interventions aimed at reducing physical work demands related to manual handling, musculoskeletal symptoms, and process variables, categorized into the effectiveness of measures and the effectiveness of implementation strategies. The numbers 1–3 refer to the objectives of this review.

"programme evaluation" or "process evaluation" (group 1), "work" or "industry" or "job" or "trade" or "task" or "employment" or "occupation" or "vocation" (group 2), and "manual handling" or "manual materials handling" or "lifting" or "carrying loads" or "carrying materials" or "pushing loads" or "pushing materials" or "pulling loads" or "pulling materials" (group 3).[4] The words belonging to group 1 were combined with "AND" with the words belonging to group 2 and group 3. In addition, Nioshtic-2 was consulted for the period after the closing of Nioshtic with the words (handling or lifting or carrying or pushing or pulling). Relevant references were also checked in the retrieved articles and reviews—this is known as the so-called "snowball method".

Articles and reports were included in this review if they met all three of the following inclusion criteria: (i) the intervention of an (ergonomic) measure or implementation strategy was aimed at reducing the physical work demands in work situations, (ii) the physical work demands as a dependent variable or, in the case of an implementation strategy, an intermediate process variable was measured, and (iii) the articles had to be available and published in English.

The intervention measures were categorized as technical measures (ie, engineering controls), organizational measures (ie, administrative controls), or individual measures (ie, individual training or education). The implementation strategies were classified as informational, compulsory, educational, persuasive, or facilitative strategies (11). The physical work demands associated with manual handling were defined as lifting, carrying, pushing, or pulling materials or persons. The classification of Van der Beek & Frings-Dresen (17) was used to assess methods for measuring external exposure. In general, external exposure measurements of forces, movements, and postures can be obtained by estimation made on the basis of (i) subjective judgments, (ii) observations (on the worksite and retrospectively from video recordings), and (iii) direct measurements.

If an included study measured the physical work demands and musculoskeletal symptoms as dependent variables, then both effect measures were reported in order to answer the second part of questions i and iii. For the musculoskeletal symptoms, all of the original measurements, from self-reported discomfort in the short term to injury records over a longer time frame, were included in this review. Short-term measurements must have represented local body areas on the assumption that fatigue or discomfort of a local body region is the first sign of emerging musculoskeletal disorders.

To gain insight into the effectiveness of ergonomic measures and implementation strategies, we have included all of the effects on physical work demands and musculoskeletal symptoms. The studies that tested the results statistically are indicated in the tables. For the classification of the process variables, if implementation strategies were aimed at reducing physical work demands, a distinction was made between the following four process measures on the basis of a classification of the seven phases of implementation from van der Molen et al (11): (i) awareness (knowing risk factors and measures to reduce physical work demands), (ii) attitude (wanting, intention to change, motivation) (iii) ability [being able to change behavior (eg, skills, availability of lifting aids)], and (iv) behavior (changing and maintaining behavior).

The study design was qualitatively described along the following two dimensions: (i) field or laboratory and (ii) experimental, quasi-experimental, pre-post, or post only. The first dimension, field or laboratory study, reflects the type of study. The second dimension indicates the quality of the study. A (quasi) experimental design was defined as an essential element of qualitatively higher studies and was, therefore, if present, evaluated as positive. On the other hand, a pre-post or post-only design was evaluated as negative. Subsequently, the quality of the studies was, arbitrarily, assessed as high (+) or low (–).

The first author (HM) reviewed all of the articles and publications. If there was any doubt about the inclusion of a study or about the study design used, the second author (JS) also reviewed the study, and a consensus was reached. The studies were not blinded when the reviewing process was carried out.

Results

Selection of studies

The electronic search in Medline, Embase, Hseline, and Nioshtic retrieved 419 articles. The search in Nioshtic-2 retrieved an additional 47 articles or reports. Four articles and one report were found using the "snowball method". The number of selected articles and reports was reduced to a total of 85 after the abstracts were read, 50 of which involved industrial settings and 35 involved health care settings. After applying the three inclusion criteria on the whole publication, we kept 42 articles from peer-reviewed journals and 4 reports for this review.[5] More than one publication was found for two studies (18–21), which partly reported on different

4 A detailed list of text words and queries is available from the corresponding author.
5 A list of rejected articles is available from the corresponding author.

aspects of the same study. Altogether 46 articles and reports described a total of 44 studies; 18 studies were relevant for the first question, 26 studies for the second question, and 8 studies for the third question. Eight studies could be used to answer more than one question. The main results of the intervention studies concerning ergonomic measures and implementation strategies on physical work demands, musculoskeletal symptoms, and process measures are summarized in tables 1–3 and are described below.

Table 1. Studies concerning the effect of measures aimed at reducing manual materials handling on physical work demands and eventually reducing musculoskeletal symptoms. (QD = quality design, MWD = measurements of work demands, technical = engineering control, organizational = administrative control, individual = personal training or education, ↓ = significant decrease when tested statistically, ↑ = significant increase when tested statistically, = = no significant change when tested statistically)

Author	Population	Study design	QD	Intervention measure	MWD	Effect on work demands	Musculoskeletal symptoms
Mirka et al, 2002 (22)	Subject level: 12 (7 men, 5 women), college students	Laboratory, experimental	High	Technical: 2 lift-assisting devices for furniture manufacturing industry (height-adjustable)	Direct	↓ Sagittal trunk flexion, accelerations and lateral trunk flexion	
Engels et al 1998 (23)	Subject level: 12 trained nurses (2 men, 10 women); 12 female control nurses	Laboratory, quasi-experimental	High	Technical & individual: course to reduce physical workload in 4 standardized nursing tasks	Observation	After 15 months: ↓ frequency, percentage of awkward postures and movements	
Janowitz et al 1998 (24)	Company level/subject level: nursery plant workers	Field, pre-experimental, post-experimental	Low	Technical: set of handles for carrying plant containers	Observation & direct	↓ Risk index lifting and percentage trunk flexion >20 degrees	
Van der Molen et al 1998 (25)	Subject level: 2 male gypsum bricklayers	Field, pre-experimental, post-experimental	Low	Technical & organizational: mechanization; task enlargement	Observation	Mechanization: elimination carrying and lifting; task enlargement: 50% reduction in bricks handled per day	
Häkkänen et al, 1997 (26)	Subject level: female trailer assembly workers (pre:33-post:20)	Field, pre-experimental, post-experimental	Low	Technical & organizational: low cost measures in work methods, organization, tools & materials	Observation & direct	After 19 months: reduction in weights and lifting in awkward postures	
Resnick & Chaffin, 1997 (27)	Subject level: 10 healthy subjects (5 men, 5 women)	Laboratory, experimental	High	Technical: three different material handling devices aimed to eliminate manual lifting	Direct	↓ Devices with articulated arm or overhead rails induced lower hand forces (50–80 N) compared with fixed device (200 N)	
Garg & Owen, 1992 (20); Garg & Owen, 1994 (21)	Subject level: 6 female nursing students	Laboratory, experimental	High	Technical: manual lifting versus walking belt in simulation of patient handling task	Direct	↓ Walking belt induced lower hand force than manual lifting	
Kemper et al, 1990 (28)	Subject level: 10 male refuse collectors	Field, pre-experimental, post-experimental	Low	Technical & organizational: replacing dustbins with bags; re-organization from collecting from twice to once a week	Observation & direct	↑ Daily amount, average weight per "throw" and lifting frequency	
Bongers et al, 2001, (29)	Subject level: bricklayers (men, 44–43 pre-post intervention; 158–131 pre-post controls)	Field, quasi-experimental	High	Technical: devices to optimize lifting distances	Observation	After 1 year: ↓ %, duration and frequency of back and arm flexion, except frequency arm >30 degrees; = force excertion >0, 10, 25 kg	= 10 months prevalence low-back, shoulder, arm complaints
	Subject level: bricklayers' assistants (men, 17–15 intervention 39–33 controls)			Technical: mechanization transport		= %, duration and frequency of back and arm flexion; = force exertion >0, 10, 25 kg	= 10 months prevalence low-back, shoulder, arm complaints
Marras et al, 2000, (30)	Company level/subject level: 36 industry jobs (32 intervention, 4 control jobs; 142 employees: 108 men, 34 women)	Field, quasi-experimental	High	Technical & organizational: lift tables, lifting aids; redesign, equipment	Direct	After (averaged) 19 months: ↓ maximum external moment L5/S1 (lift aid), sagittal flexion trunk (lift table), lateral velocity trunk (lift table and equipment)	↓ Incidence rate low-back disorders for lift tables and aids; = redesign / equipment
Marklin & Wilzbacher, 1999 (31)	Company level/subject level: electric warehouse	Field, pre-experimental, post-experimental	Low	Technical: adjusting lifting height	Observation & direct	Risk index lifting reduced	Perceived effort low-back, arms, knees, shoulder decreased
				Technical: reducing weight of gates, increasing lever arm tool		Risk index lifting index (gates), push and pull forces (lever arm) reduced	Perceived effort shoulder (gates), low-back, shoulder, arm (lever arm) decreased

(continued)

Table 1. Continued.

Author	Population	Study design	QD	Intervention measure	MWD	Effect on work demands	Musculoskeletal symptoms
Stobbe, 1999 (32)	Subject level: 9 (2 men and 7 women) nursing assistants	Laboratory, experimental	High	Technical: 10 lifting devices for a patient handling task (bed to chair)	Observation & direct	Mechanical devices eliminated lifting of patient (standing up): reduced exposure 50% compared with manual method	↓ Perceived effort shoulder, upper and lower back
	Company level/subject level: nursing home	Field, pre-experimental, post-experimental	Low	Technical & individual: lifting devices and training		After 4 months: back injury decreased	
Nygård et al, 1998 (33)	Subject level: 21 female store workers	Field, pre-experimental, post-experimental	Low	Technical: automate, remaining lifting tasks with new bigger plastic cases for food products	Observation & direct	After ½ year: ↓ handled goods >10 kg; = total handled weight (goods); = walking distance, awkward back postures	= Perceived strain hand, neck, low-back, leg
				Individual: lifting technique	Observation	After 1 year: = total handled weight (goods), awkward back postures	= Perceived strain arm, neck, lower back, leg
Woolfrey & Kirby, 1998 (34)	Subject level: 23 health care workers (4 men, 19 women)	Laboratory, quasi-experimental	High	Individual: new work technique for moving empty wheelchair	Observation	↓ Number and duration back flexions >20°	↓ Back comfort increased
Devereux et al, 1997 (35)	Subject level: 21 male delivery drivers	Field/laboratory, pre-experimental, post-experimental	Low	Technical: cylinder handle designed through participative ergonomic approach	Observation & direct	Increase in weight upon hand in deviated wrist posture	Discomfort low back, hip & thigh increased; neck, wrist & hand, knee, shoulder decreased
Vink et al, 1997 (36)	Subject level: 3 male scaffolders (observation 2 male scaffolders)	Field, postexperimental only (reference group)	Low	Technical & organizational: mechanization of transport, decreasing weights, adaptation of logistics	Observation	Time carrying and lifting loads >20 kg reduced (from 25% to 5%); time arm elevation >60 degrees reduced from 25–30% to 7–20%	Discomfort shoulder, legs decreased; back increased
McGlothin et al, 1996 (37)	Subject level: 9 soft drink beverage driver-sales workers	Field, pre-experimental, post-experimental	Low	Technical: engineering controls at truck, reduce weight containers, two-wheel hand truck, better coupling, new rollers indoor	Observation	Risk index lifting decreased; ↓ 7.8 lb[a] force reduction to lift / lower bay doors	= Discomfort after 6 weeks of back, shoulder, elbow
Johansson et al, 1993 (38)	Subject level: 28 male truck-axle workers versus 17 workers in old system (observation: 8 versus 16 workers)	Field, post-experimental only (reference group)	Low	Technical & organizational: paralleled assembly lines with longer job cycle time and job enlargement compared with old un-paced line assembly system	Observation	↓ duration back flexion >40 degrees (7 versus 2%); ↑ duration manual materials handling (27 versus 41%)	= 12 months prevalence in all body regions

[a] 1 lb = 454 g.

Table 2. Studies concerning the effect of implementation strategies aimed at reducing manual (materials) handling on process variables. (QD = quality design, UK = United Kingdom, ↓ = significant decrease when tested statistically, ↑ = significant increase when tested statistically, = = no significant change when tested statistically)

Author	Population	Study design	QD	Intervention strategy	Methods	Effect on process
Johnsson et al, 2002 (39)	Subject level: 51 health care workers (7 men, 44 women)	Field, quasi-experimental	High	Informational + educational: patient handling skills; two groups: 4 days versus 8 meetings during 4–6 months	Questionnaire, observation	Behavior (after 6 months): ↑ 92% used new techniques (almost) always; = between groups
de Jong & Vink, 2002 (40)	Company level/subject level: installation company (7000 workers) / 12 health and safety experts	Field, post-experimental only	Low	Informational + facilitating: 6 steps with steering group and direct participation of workers, oral (meeting) and written information (brochure) aimed to reduce physical work demands	Questionnaire	Behavior (after 18 months): 114 mechanical lifting or carrying devices were bought with varying reported frequencies of use
Daynard et al, 2001 (41)	Subject level: 24 nursing personnel	Field, experimental	High	Educational + facilitating: back care, lifting technique, patient assessment, use of equipment; two groups: identical programs but one group supplied with new lifting equipment	Observation	Behavior: ↑ correctly conducted simulated patient handling activities 25% higher in group with new equipment (44% versus 69%)
Hignett, 2001 (42)	Department level: wards and departments of a hospital (5000 staff members)	Field, pre-experimental, post-experimental	Low	Informational + educational + facilitating: steering groups, involvement of all levels in organization, risk assessment, furniture and lifting aids, mobility and communication system on patient, training	Checklist	Awareness + ability (after 5 years): completed risk assessments and actions for manual handling from 33% to 76%
de Jong & Vink, 2000 (43)	Company level: 412 glazier companies (response rate 20%)	Field, post-experimental only	Low	Informational + compulsory + educational + facilitating: project in three companies to use equipment; campaign on national level with brochure, standard, video, practicing equipment on exhibition	Questionnaire	Awareness + ability + behavior (after 12 months): 88% aware of lifting devices; 55% bought and used at least one device

(continued)

Table 2. Continued.

Author	Population	Study design	QD	Intervention strategy	Methods	Effect on process
Lynch & Freund, 2000 (44)	Subject level: patient handling staff (pretrained 164, posttrained 59, references 45)	Field, post-experimental only (reference group)	Low	Educational + facilitating: 1-year back injury prevention program with ergonomic evaluation, testing and purchase of new equipment, train the trainer (8 hours), training staff (1 hour)	Questionnaire	Awareness + ability+ behavior (30–60 days after training): ↑ knowledge about risk factors, = use mechanical devices
					Checklist	↓ Repositing patients in bed; more equipment needed
Evanoff et al, 1999 (45)	Subject level: orderlies; 67 (pre)-88 (post)	Field, pre-experimental, post-experimental	Low	Informational + educational + facilitating: 8 hour training for team which implemented manual of 12 lift protocols, training and feedback of supervisor and co-workers	Questionnaire	Attitude (after 7 months): = and after 15 months: ↑ job satisfaction and social support
Jones et al, 1999 (46)	Department level/ subject level: 25 pairs of subjects from 25 departments of a teaching hospital	Field, post-experimental only (reference group)	Low	Informational + educational: guide manual handling and training one group; only guide other group; both compared with ergonomist (golden standard)	Checklist	Awareness + ability: = assessment, proposed solutions between groups; both groups able to identify hazards; half of assessments considered adequate or very good compared with ergonomist; after 6 months 71 of 233 solutions implemented
Knibbe & Friele, 1999 (47)	Subject level: 378 female home care nurses (139 versus 239 controls)	Field, quasi-experimental	High	Informational + educational + facilitating: 40 patient hoists, training, assessment forms, 12 lifting coordinators	Checklist	Behavior (after 1 year): use of hoists from 24.6% to 56.7%; controls 27.7% (pre)-27.5% (post)
Lagerström et al, 1998 (19)	Subject level: 348 female nurses	Field, pre-experimental, post-experimental	Low	Educational: patient transfer technique, fitness exercise, stress management	Questionnaire	Attitude + behavior (after 4 years): ↑ to technique (from 97 to 99%), used transfer devices (from 63 to 71%), transfer alone instead of 2 persons (from 11 to 16%); = use of work technique, patient cooperation
Laitinen et al, 1998 (48)	Department level/ subject level: 300 employees in 11 metal railway departments; questionnaire 1: 93–96, questionnaire 2: 64–63	Field, pre-experimental, post-experimental	Low	Educational + facilitating: 11 project groups trained in 4-hour seminars, set goals and implement measures on tools and materials; all workers participated in a 2-hour starting seminar; 20 persons received a 5-day course on ergonomics; workers' safety representative was trained to be an internal consultant	Questionnaire 1, questionnaire 2	Ability + behavior (after 4–5 months in 6 departments): ↑ right work methods (57% to 89%), working conditions, psychosocial work environment; = support, own resources, hygiene, stimulus work; after 9 months in 4 departments: ↑ communication, cooperation and tools
Monaghan et al, 1998 (49)	Department level/ subject level: 178 nurses at 8 locations	Field, post-experimental only	Low	Informational + educational + facilitating: training (of trainers), equipment, patient assessment and care plans, publicity	Interview, checklist	Awareness + ability (after 9 months): 79% thought program worked well; 68% had practical problems; 45% knew standards; 52% felt they had enough equipment; 75% of patients had a mobility care plan of which 55% reported the equipment and 67% the number of nurses required
Jones, 1997 (50)	Company level: 13 poultry processing plants	Field, pre-experimental, post-experimental	Low	Informational + educational + facilitating: committees, surveillance education, medical management, self assessment	Checklist	Awareness + ability (after 3 years) increase from 55% to 93% in completed assessment scores
Vink et al, 1997 (36)	Subject level: 13 male scaffolders	Field, post-experimental only	Low	Facilitating: steering committee tested and selected with workers: mechanization, decreasing mass of scaffolding elements, redesign of work organization and training	Questionnaire	Attitude +behavior (after 6 months): 88% used pallet truck, lighter weights, shoulder protection; 53% cleaned scaffold, trained lifting; 30% used electrical winch, logistics, work preparation plan; most measures were judged as positive for reducing physical work demands
Schenk et al, 1996 (51)	Subject level: 205 healthy volunteers from a local industry (161 men and 44 women; groups 1, 2 and 3: N=74, 64, 67)	Field, post-experimental only (reference groups)	Low	Informational + educational: cognitive learning and practice 2 hours (group 1), instruction video ½ hour (group 2), no education (group 3: reference group)	Questionnaire, direct measurement	Awareness + attitude + behavior: after one week: ↑cognitive, affective (wanting the program) measures, lifting lordosis posture in group 1; = groups 2 and 3
Garb & Dockery, 1995 (52)	Department level/ subject level: perioperative personnel	Field, post-experimental only	Low	Educational + facilitating: training in patient lifting, longer roller boards, larger draw sheets, teamwork, other beds, maintenance floor and equipment, new wheels, rubber-soled shoes	Questionnaire	Awareness + attitude (after 6 months): less than half of personnel aware of ergonomic changes and believed they were somewhat helpful
Moore, 1994 (53)	Subject level: 4 flywheel assembly workers	Field, post-experimental only	Low	Facilitating: employee and supervisor participation and strong engineering support resulting in elimination of hammering	Questionnaire	Attitude: all workers more satisfied with revised job requirements and evaluated implemented solution appropriate; 2 workers felt job better, 2 felt no change
Woodruff et al, 1994 (54)	Subject level: 1772 male navy recruits of 1 month; 1658 male in reference group 1 month later	Field, post-experimental only (reference group)	Low	Informational: Information mainly on back mechanics and safe lifting techniques	Questionnaire	Awareness: ↑ knowledge in intervention group (67% correct) compared to references (50% correct)

(continued)

Table 2. Continued.

Author	Population	Study design	QD	Intervention strategy	Methods	Effect on process
Young et al, 1994 (55)	Company level: 13 abattoirs	Field, pre-experimental, post-experimental	Low	Compulsory: work inspectorate also targeting manual handling	Question-naire	Awareness + ability (after 2 months): from 60 to 90% awareness legislation; from 0 to 70% manual handling policy; from 40 to 90% implemented procedures; from 46 to 92% implemented measures
Daltroy et al, 1993 (56)	Subject level: 209 postal workers out of 4000 for program (134 men, 75 women; 89 trained experimental group, 31 untrained experimental group, 89 reference group)	Field, post-experimental only (reference group)	Low	Informational + educational: social learning theory by physical therapists in groups of 10–12; 3-hour class session, reinforced every 6 months, with information, skills for lifting, exercises and techniques to reduce biomechanical stress; individual work station assessment to small groups of workers and supervisors	Question-naire	Awareness + behavior [after 2½ years (midway program)]: ↑ knowledge about safe lifting and postures in trained group and untrained experimental group compared with reference group; = behavior associated with back health
Scopa, 1993 (57)	Subject level: nursing staff hospital; N=27 (7 men, 20 women) for classroom; N=22 (5 men, 17 women) for self-learning	Field, experimental	High	Informational + educational: classroom instruction in body mechanics as a 2-hour presentation of straight back and bent-knee lifting technique versus an independent study of a written self-paced learning module	Observa-tion	Behavior: (after 1 month): = on-the-job body mechanics behavior
Wickström et al, 1993 (58)	Subject level: 125 male sheet metal workers and 88 male planners	Field, pre-experimental, post-experimental	Low	Informational + educational + facilitating: steering groups 1–2 hour/month/year; providing groups ergonomic information; presentation mechanics lumbar spine; fitness	Question-naire	Behavior: ↑ sheet metal workers that followed ergonomic principles and used mechanical equipment to avoid awkward work postures and lifting
Garg &Owen, 1992 (20); Garg &Owen, 1994 (21)	Subject level: 57 nursing assistants (3 men, 54 women)	Field, post-experimental only	Low	Informational+ educational + facilitating: ≥2 sessions of 2 hours applying devices/ techniques, modified shower rooms & toilets, coding patients, maintenance	Observa-tion	Behavior (after 4 months): 81% use of walking belt; after 8 months 87% use of mechanical hoist for patient transfer
Tesh et al, 1992 (59)	Company level: 5 industrial companies	Field, post-experimental only	Low	Informational: use and implementation of manual handling guidelines (UK legislation); guidance in avoidance of hazardous operations, assessment and reduction of remaining risks	Interview, checklist	Awareness + ability: 25% of all assessments disagreed with ergonomists; guidance needed for value judgement; lifting aids or organizational changes introduced in case of risks; many lifting aids remained unused (new risks, bad design)
Hocking, 1991 (60)	Company level/department level: external plant staff of telecom plant	Field, post-experimental only	Low	Informational + educational + facilitating: 41 (engineering) projects, training, instruction, publicity	Observa-tion, question-naire	Ability (after 7 years): 11 out of 14 improvements
Feldstein et al, (61) 1990	Subject level: 55 nurses, aides and orderlies (7 men, 23 women in intervention group; 4 men, 21 women in control group)	Field, quasi-experimental	High	Educational + facilitating: patient handling, exercise and environmental changes at a medical unit in one center; unit in another center served as control	Observa-tion	Behavior: after 1 month in 4 transfer tasks: ↑ 19% improvement in quality of patient transfer; = improvement in transfer set ups (combination of number patient handlers and equipment used)

Table 3. Studies concerning the effect of implementation strategies aimed at reducing manual (materials) handling on physical work demands and eventually on musculoskeletal symptoms. (QD = quality design, MWD = measurements of work demand, ↓ = significant decrease when tested statistically, ↑ = significant increase when tested statistically, = = no significant change when tested statistically)

Author	Population	Study design	QD	Intervention measure	MWD	Effect on work demands	Musculoskeletal symptoms
de Jong & Vink, 2002 (40)	Company level/subject level: large installation company (7000 workers)	Field, pre-experimental, post-experimental	Low	Informational + facilitating: 6 steps with steering group and direct participation of workers, oral (meeting) and written information (brochure) aimed to reduce physical work demands	Ob-serva-tion & self-report	Reduction in duration of lifting and carrying materials with 4 mechanical devices (up to 29%); less perceived lifting (height)	
de Jong & Vink, 2000 (43)	Company level: 128 glazier companies (response rate 6.2%)	Field, post-experimental only	Low	Informational + compulsory + educational + facilitating: project in three companies to use equipment; campaign on national level with brochure, standard, video, practicing equipment on exhibition	Self-report	After 12 months: = reported reduction in work demands associated with use equipment	
Keyserling et al, 1993 (62)	Company level/subject level: 151 jobs in metal-, stamping- and engine plant, two distribution warehouses	Field, pre-experimental, post-experimental	Low	Educational + facilitating: program with 1-week training for worksite analysis and hazard reduction	Ob-serva-tion	After 12 months: ↓ duration trunk flexion (>45º) and arm elevation (>45º); ↑ frequency neck flexion (>45º)	

(continued)

Table 3. Continued.

Author	Population	Study design	QD	Intervention measure	MWD	Effect on work demands	Musculoskeletal symptoms
Yassi et al, 2001 (63)	Subject level: 346 nurses (assistants) from 3 types of wards	Field, experimental	High	Educational + facilitating: training and lifting equipment; two intervention groups (see table 2 Daynard et al) and 1 control group	Self-report	After 6 months: ↓ frequency in manual patient lifts and transfers with 10 (when extra lifting equipment) and 3 / shift; after 12 months: = ↓ dependent on type of ward	↓ One-week prevalences low back and shoulder pain; = Injury rates
Knibbe & Friele, 1999 (47)	Subject level: 378 female home care nurses (139 versus 239 controls)	Field, quasi-experimental	High	Informational + educational + facilitating: 40 patient hoists, training, assessment forms, 12 lifting coordinators	Self-report	After 1 year: ↓ number of patient transfers per nurse/ week from 35 to 21	↓ 12-month back pain prevalence
Lagerström & Hagberg, 1997 (18); Lagerström et al, 1998 (19)	Subject level: 348 female nurses	Field, pre-experimental, post-experimental	Low	Educational: patient transfer technique, fitness exercises, stress management	Self-report	= after 4 years: % workers with >10 patient transfers per shift	↑ 12-month prevalence upper back and hip; = other regions
Moore, 1994 (53)	Subject level: 5 assembly workers	Field, pre-experimental, post-experimental	Low	Facilitating: employee and supervisor participation and strong engineering support resulting in elimination of hammering	Observation	Elimination of hammering; no change in lifting	After 30 months: decrease frequency and duration reported disorders
Wickström et al, 1993 (58)	Subject level: 125 male sheet metal workers and 88 male planners (reference company for low-back pain)	Field, pre-experimental, post-experimental	Low	Informational + educational + facilitating: steering groups 1–2 hour/month/ year; providing groups ergonomic information; presentation mechanics lumbar spine; fitness	Self-report	After 4 years: ↓% sheet metal workers that considered mechanical loads at work to contribute to low-back pain (from 56 to 29%); = planners	= 12-month prevalence low-back pain

Effects of ergonomic measures on physical work demands and musculoskeletal symptoms

Eighteen studies (20–38) measured the effect of ergonomic measures on physical work demands (table 1). Four of these studies are concerned with patient handling (20–22, 31, 33), and the others with manual materials handling in different populations of industrial workers. Most of the studies reported reductions in physical work demands after the introduction of technical engineering controls.

The effect of technical measures was reported in eight studies (20–22, 24, 27, 29, 31, 35, 37). A decrease in physical work demands was measured in seven out of eight interventions (20–22, 24, 27, 29, 31, 37). Six interventions (25, 26, 28, 30, 36, 38) combined technical and organizational measures, of which four reported a reduction in physical work demands (25, 26, 30, 36). The interventions that combined individual and technical measures (23, 32, 33) or only involved individual measures (34) reported a decrease in physical work demands. Ten studies (29–38) also determined the effect of measures on musculoskeletal symptoms (table 1). These effects were not univocal because only four studies reported a decrease in symptoms (30–32, 34).

Four experimental laboratory studies, simulations of daily manual handling tasks, analyzed the effect of technical measures on physical work demands. Mirka et al (22) measured lower peak trunk flexions and accelerations due to height-adjustable industrial lifting devices. Resnick & Chaffin (27) found large variations in peak hand forces when studying three different material handling devices with the highest force for the fixed pivot hoist. Two studies showed a reduction of the physical work demands due to lifting devices for patient handling (20, 21, 32). Two quasi-experimental laboratory studies reported a significant improvement in the frequency and percentage or duration of awkward postures in standardized tasks due to training in work techniques (23, 34).

Two more quasi-experimental field studies in industry measured the effect of mechanical engineering controls on physical work demands and on musculoskeletal symptoms. Marras et al (30) showed significant reductions in physical work demands and reductions in the incidence rate of low-back disorders during a follow-up of an average of 19 months as a result of lift tables and lifting aids. Using lifting devices to adapt the work height of bricklayers resulted in significant reductions in awkward postures of the back, arm, and wrist, but showed no effects on the 10-month prevalence of musculoskeletal symptoms in the back, shoulder, and wrist (29). As expected, no change in force exertion was found. Bricklayers' assistants mechanization of manual transport had no effects on physical work demands and musculoskeletal complaints.

Effects of implementation strategies on process measures

Twenty-six field studies (19, 20, 21, 36, 39–61) analyzed the effect of implementation strategies on various (intermediate) process measures (table 2). Eight of these studies consisted of a combination of informational, educational, and facilitative strategies. Eleven consisted of a combination of educational and facilitative strategies, a combination of informational and facilitative strategies, or a combination of educational and informational strategies. One study covered four strategies and six studies focused on one strategy. Altogether, 21 of the 26 implementation strategies that measured an improvement in process outcomes used a participatory ergonomic approach (36, 40–45, 48–50, 53, 58), an education (or training) program (19–21, 39, 41, 47, 51, 52, 56, 60, 61), or both with the direct involvement of workers.

Studies reporting changes in attitudes and behavior involved practicing the targeted interventions before implementing them, the participation of workers, and the facilitation of engineering controls (technical measures) or compliance by labor inspectorates. Some showed increased awareness through informational strategies. Two studies using reference groups (51, 56) indicated that an informational strategy alone is not sufficient to change behavior in order to reduce physical work demands.

One experimental study found no differences in lifting techniques between people who had received classroom instruction (educational strategy) or who had studied a self-paced learning module (informational strategy) (57). One other experimental study (41) and three quasi-experimental studies (39, 47, 61) demonstrated significant improvements in behavior aimed at reducing physical work demands as the effect of a combination of implementation strategies. Johnsson et al (39) found improvements in the work technique of health care workers due to a training program (information and education), but no differences between two models of learning. Daynard et al (41) showed greater compliance with interventions that combined training (education) with new patient-handling equipment (facilitation) compared with training alone. Knibbe & Friele (47) reported that, due to a combined intervention strategy of assessment forms (information), training (education), and lifting devices and lifting coordinators (facilitation), the use of mechanical devices increased in an intervention group of home care nurses but not in the control group. Feldstein et al (61) reported improvements in the quality of patient transfers, while the improvements in the number of persons for each patient transfer and equipment used after a program consisting of education (training and exercise) and facilitation (environmental changes) were not statistically significant.

Effects of implementation strategies on physical work demands and musculoskeletal symptoms

The evidence of the effectiveness of (combinations of) implementation strategies in the work situation on the reduction of physical work demands and eventually on the musculoskeletal symptoms (table 3) associated with manual handling is presented on the basis of eight studies (18, 19, 40, 43, 47, 53, 58, 62, 63) retrieved for this review. These eight longitudinal studies showed mixed results for both physical work demands and musculoskeletal symptoms. Three studies aimed at reducing physical work demands with patient handling (18, 19, 47, 63) and five with manual materials handling in a broad range of industrial settings (40, 43, 53, 58, 62). All of the studies consisted of a facilitation strategy (ie, participatory approaches or availability of lifting aids) or education.

The two most rigorous studies (47, 63) indicated that a combination of implementation strategies, including facilitation and education, resulted in a significant reduction in physical work demands and musculoskeletal symptoms. In a three-armed randomized controlled trial, Yassi et al (63) showed that a combination of assured availability of mechanical and assistive patient-handling equipment (facilitation) and training (education) most effectively reduced physical work demands and, to a less degree, week prevalences of low-back and shoulder pain among health care workers. Knibbe & Friele (47) showed that lifting devices and lifting coordinators (facilitation), training (education), and assessment forms (information) resulted in a significant reduction in physical work demands and a significant reduction in the 12-month prevalence of back pain among home care nurses.

Discussion

A significant reduction in physical work demands and musculoskeletal symptoms was found when (mechanical) lifting devices were part of the intervention. In addition, laboratory studies on standardized daily work-tasks were found to be useful for assessing the efficacy of interventions on physical work demands and, eventually, short-term musculoskeletal symptoms (20–23, 27, 32, 34). The higher quality studies that showed improvements in behavior (39, 41, 47, 61) indicated the importance of facilitating and educational strategies. Ultimately, changing workers' behavior is a necessary condition for reducing physical work demands and musculoskeletal symptoms in the longer run when ergonomic measures are implemented.

Inclusion criteria

The ultimate objective of this systematic review was to produce insight into the effectiveness of measures and strategies by applying a broad search strategy. The inclusion criteria appeared rather strict when applied to the retrieved studies. In addition to implementation studies that measured process variables, only studies that actually measured physical work demands as dependent variables were included. Consequently, many studies that evaluated other dependent variables were not included. Evaluating the effect on physical work demands was an a priori choice because we assumed that most interventions in manual handling aim to reduce physical work demands. Another objective of this review was to search for interventions that reduce musculoskeletal symptoms by reducing physical work demands. Many studies that measured musculoskeletal symptoms of body regions, but not combined with measurements of physical work demands, were excluded from this review.

Selection of the literature

A sensitive electronic search strategy was used. It was achieved by using synonyms or truncation of free text words in the title, abstract, or subject heading of articles and reports and by means of the "snowball method". In the end, 471 references were retrieved, almost 10% of which were found relevant for this review, indicating a relatively high sensitivity level but consequently lower specificity. The selection of databases, the restriction to the English language, and the possibility that other articles used different free text words implies that some relevant studies could have been missed.

Study design and methodological quality

Experimental or quasi-experimental study designs are not always applicable or feasible in evaluation studies on occupational health and safety in daily practice (64, 65). Since the aim of this systematic review was to study the effectiveness of ergonomic measures and implementation strategies on physical work demands and musculoskeletal symptoms, all study designs were included and a qualitative judgment about the study design was made afterwards. However, longitudinal, controlled field studies in particular are important for establishing causal relationships between interventions and effect. In addition, experimental laboratory studies on standardized daily worktasks are useful for assessing the efficacy of interventions. Descriptive studies can support the reported effects of controlled studies, although these kinds of studies are more likely to overestimate the effect of intervention (66). In addition, knowledge of less rigorous studies is desirable in order to select feasible interventions in daily work practice and, therefore, to increase external validity. Only some higher quality longitudinal (quasi-)experimental field studies were found that analyzed the effect of ergonomic measures or implementation strategies on physical work demands.

Evaluation of measures affecting physical work demands and musculoskeletal symptoms

As stated by Engels et al (23), it is not easy to translate the results of a laboratory study into daily practice. However, all of the laboratory studies in this review were simulations of daily manual handling tasks and, therefore, evaluated the efficacy of measures in a standardized setting. In general, the field studies showed reductions in physical work demands due to different kinds of ergonomic measures. These measures were often a combination of engineering and administrative controls or engineering controls only. Kemper et al (28) reported an increase in physical work demands, but it is worth noting that the primary aim of the study was to measure the effect of a reorganization and it was not, as such, an action only intended to reduce manual materials handling among refuse collectors.

The hypothesis that the effect of interventions on physical work demands has a subsequent effect on musculoskeletal symptoms may be ambiguous with respect to the last part of this hypothesis. This ambiguity can partly be explained by the multifactorial nature of these symptoms and the time frame of the measurements. Waddell & Burton (67) found strong evidence for manual materials handling as a risk factor for the incidence of low-back pain, but rated the magnitude of this effect as less than other individual, nonoccupational, and unidentified factors. In a study on the interrelations between low-back pain and manual handling among scaffolders, Elders & Burdorf (2) suggested that work-related risk factors may vary according to the use of different definitions for low-back pain. The standardization of methods to assess the different end points of musculoskeletal symptoms in the short and longer terms should be given more attention in prospective studies.

In this review, many studies reported that ergonomic measures, particularly technical measures, reduce physical work demands during manual handling. There are indications, however, that ergonomic measures that actually reduce the physical work demands in work situations will also reduce musculoskeletal symptoms.

Evaluation of the implementation strategies on process variables

Remarkably many studies were found that analyzed the effect of implementation strategies on different process variables. Process data are usually more sensitive and more informative measures of the quality of implementation when compared with outcome data (69, 70) and less liable to cause confounding. In the implementation process, it is important for the different actor groups to go though several cognitive phases (71, 72) and process phases that contain a facilitative policy (eg, buying equipment, training skills) (11). First of all, the actor groups involved in the implementation must be "aware" of the problems and (ergonomic) measures associated with manual handling (awareness). Second, they must "want" these changes (attitude), and, finally, the target group has to "change their behavior" in the short and longer terms (behavior). This process has to be facilitated in such a way that the target group can actually change its behavior (ability) (eg, availability of lifting devices and training).

Although a change in behavior is often the ultimate goal of an implementation strategy, the results of this review indicated that it seems that influencing and evaluating the "awareness", "attitude", and "ability" phases is also essential. Every phase may require a different implementation strategy. Implicitly, most implementation strategies recognized these phases by adopting a participatory approach to implement ergonomic measures, but the phases of the approach were not evaluated separately in most studies. Moreover, each approach varied in content, intensity, frequency of feedback, and duration. Ideally, an implementation study should be evaluated according to a range of intermediate process and end-point outcome variables (64). In this review one experimental study (57) explicitly evaluated one implementation strategy, which is preferable from a purely scientific point of view.

Evaluation of implementation strategies with respect to physical work demands and musculoskeletal symptoms

The differentiation between interventions with (ergonomic) measures and implementation strategies was based on a similar distinction in another area of research. Grol & Jones (68) concluded that evidence-based health care should be complemented by the evidence-based implementation of quality improvement and quality management. Understanding both the barriers and opportunities that are involved in the implementation phases and the research methodologies to evaluate these implementation phases is seen as an essential element in implementation studies. On the basis of the results of this review, it can be hypothesized that the success of an intervention aimed at reducing the physical work demands associated with manual (materials) handling and musculoskeletal symptoms is not only dependent on the effectiveness of the ergonomic measures, but also on the implementation strategy. As far as the authors are aware, no such distinction was clearly made and evaluated in another systematic review of the effects on physical work demands and musculoskeletal symptoms.

It can be argued that a study classified as an intervention strategy should not be classified as an intervention measure, or more likely a combination of both. Nonetheless, for all of the retrieved studies, the definitions of the (ergonomic) measures and implementation strategies used were found to be adequate when the different interventions were classified along the operationalized objectives of this review. However, only five implementation studies were found that actually measured both physical work demands and musculoskeletal symptoms. Two higher quality studies (47, 63) suggested that technical measures and a combination of implementation strategies reduce physical work demands and musculoskeletal symptoms. At least the following five different implementation strategies can be distinguished (11): (i) informational, (ii) compulsory, (iii) educational, (iv) persuasive, or (v) facilitating strategies. No persuasive strategies were found in this review. The higher quality studies (47, 63) combined at least two strategies, namely, training (educational strategy) and the availability of lifting equipment (facilitating strategy).

Concluding remarks

Reductions in physical work demands and low-back disorders were found when (technical) lifting devices were part of the intervention. Laboratory studies on standardized daily worktasks were useful for assessing the efficacy of intervention measures on physical work demands and short-term musculoskeletal symptoms. Most of the implementation strategies that measured positive effects for process variables used a participatory (ergonomic) approach, an education (or training) program, or both with the direct involvement of workers.

Recommendations

For manual handling at work, a minimum combination of engineering ergonomic controls facilitated by an implementation strategy of facilitation (eg, participatory approach, an educational approach, or both) with the direct involvement of the workers seems to be the best intervention to reduce physical work demands and related musculoskeletal disorders in the longer term. For intervention research aimed at reducing physical work demands in association with manual handling, it is important to make a distinction between the ergonomic measures themselves and the strategies to implement these measures. More (quasi) experimental field studies should be conducted to establish the efficacy and effectiveness of ergonomic measures and strategies.

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