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IN-DEPTH REVIEW

Finding ergonomic solutions—participatory approaches

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Abstract This paper gives an overview of the theory of participatory ergonomics interventions and summary examples from a range of industries, including health care, military, manufacturing, production and processing, services, construction and transport. The definition of participatory approaches includes interventions at macro (organizational, systems) levels as well as micro (individual), where workers are given the opportunity and power to use their knowledge to address ergonomic problems relating to their own working activities. Examples are given where a cost-effective benefit has been measured using musculoskeletal sickness absence and compensation costs. Other examples, using different outcome measures, also showed improvements, for example, an increase in productivity, improved communication between staff and management, reduction in risk factors, the development of new processes and new designs for work environments and activities. Three cases are described from Canada and Japan where the participatory project was led by occupational health teams, suggesting that occupational health practitioners can have an important role to play in participatory ergonomics projects.

Key words Interventions; manual handling; musculoskeletal disorders; participatory ergonomics; WRULD.

Introduction

Finding ergonomic solutions to workplace musculoskeletal disorders (MSDs) can range from micro issues, which require individual design for a single user workstation, to macro issues looking at systems for both strategic direction and operational processes. Participatory ergonomics (PE) has much to offer as a descriptor [1] of a number of different approaches used to tackle problems at both these levels. Historically, MSDs have been tackled with expert input at a micro level, with mixed results. However, as this paper will show, participatory interventions at macro levels also have much to offer.

The paper starts by exploring definitions for PE and then goes on to provide summaries of intervention projects which used PE approaches. A number of different industrial sectors are included: health care, military, manufacturing, construction, production and processing, services and transport.

The aims of this review are firstly to show how participatory approaches have been used to find ergonomic solutions in different industrial and occupational health settings, and secondly to give outline descriptions of these programmes together with cost-effective evaluations where available.

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Review methodology

For this narrative, review data were sought from three main databases: Ergonomics Abstracts, Medline and CINAHL using the search terms participat * and ergonomic * . The majority of the literature on PE was drawn from three sources [2–4].

Participatory ergonomics

Participatory ergonomics can be very simply described as a concept involving the use of participative techniques and various forms of participation in the workplace [1]. Wilson [5] defined participation in ergonomics projects 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'.

There are differences in the understanding and application of PE projects between the USA and Europe. In the USA, PE tends to be used at a macro-ergonomics level, for the development and implementation of technology [6,7]. In Europe, PE approaches have been applied at all levels of ergonomic interventions, with the key factor being the involvement of all stakeholders in the project [8–11].

Table 1. Participatory ergonomics framework, ranked in order of importance

Order ranking	Dimension	Extent of dimension
1.	Decision-making	Group delegation—group consultation—individual consultation
2.	Mix of participants	Operators—supervisors—middle management—union personnel—specialist/technical staff—senior management
3.	Remit	Process development—problem identification—solution generation—solution evaluation—solution implementation—process maintenance
4.	Role of ergonomics specialist	Initiates and guides process—acts as team member—trains participants—available for consultation
5.	Involvement	Full direct—partial direct—representative
6.	Focus	Designing equipment or tasks—designing jobs, teams or work organization—formulating policies or strategies
7.	Level of influence	Entire organization—department/work group
8.	Requirement	Compulsory—voluntary
9.	Permanence	On-going—temporary

A recent review of the literature on PE [4] reported a shift towards reports and reviews of methods and approaches, which suggests that PE is a maturing approach, moving beyond the initial conceptual development and single applications into implementation and evaluation. It was noted that although a participatory approach was generally considered to be beneficial there were rarely reports from projects that had limited or no benefit from participatory interventions and that there was 'often a lack of quality evaluation'. A possible reason for the relative lack of publications might be that practitioners are reluctant to publish apparent failures. The lack of quality evaluations may be due to two factors. Firstly, a company is less interested in evaluating the project if the outcome has not been favourable. Secondly, a company does not see the need for evaluation if the project has been a success. In this case, there may also have been significant reorganization within the company that can limit a pre/post-evaluation protocol.

The latter is a common problem with studies where the variables impacting on the outcome measures may be difficult to control. These concerns can be addressed if a more systematic approach is taken to case study research. Case study is defined by Yin [12] as 'a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence'. It refers to research that investigates a few cases or even just one case (situation, site, group, individual or organization) in considerable depth using both qualitative and quantitative data [13,14]. The flexible nature of case study research allows for the real world changes that are very likely to occur during a PE project.

A framework for participatory ergonomics projects

A number of authors have suggested typologies for employee participation in order to explore the degree of involvement of employees in decision-making [15,16]. This ranges from a top-down approach with information flowing from management to workers on plans for action; gathering of information and experience from workers; consultation where workers can make suggestions and present points of view; negotiations in formalized committees; through to joint decision-making in agreement between involved parties [16].

There has been considerable effort in the last few years to develop a framework for PE projects with initiatives supported by the Health & Safety Executive [2] and the European Trade Unions Technical Bureau for Health and Safety working in co-operation with The National Institute for Working Life and the Swedish Trade Unions (SALTSA) [4,17].

One of the most recent and comprehensive projects to define the dimensions in PE approaches was presented and validated (with an order ranking) at a European workshop—the Participatory Ergonomics Framework (PEF) [18] as shown in Table 1. One result of this workshop is more research work on the framework to see how it can be further adapted.

The ranked dimensions highlight the importance of the involvement of workers, with the top two relating to consultation in decision-making and involvement of workers at all levels in an organization. It is interesting to note that the permanence of the ergonomics input was ranked as the lowest, suggesting that ergonomic input is perhaps project-specific rather than a permanent organizational role.

Tools of participation

The tools used in PE depend on the social, organizational and industrial context and must allow for a progression from practical to abstract and conceptual issues. This may mean that a combination of quantitative and qualitative data are required and can be collected using a variety of methods [19].

Haines and Wilson [2] categorized the methods and techniques used in PE as shown in the box:

1. Problem analysis, e.g. link analysis, Pareto analysis, activity anlaysis.
2. Creativity stimulation and idea generation, e.g. round robin questionnaire word map.
3. Idea generation and concept development, e.g. scenario driven discussion, design decision group, focus groups.
4. Concept evaluation, e.g. layout modelling and mock-ups, intervention ideas, checklists.
5. Preparation and support, e.g. team formation and building.

The practicality of tools is important as the educational background of the participants may be heterogeneous. It may be useful to start with a hands-on exercise, e.g. simulations or mock-ups, and then progress into problem-solving, from idea generation and concept evaluation, ending in an action proposal with a recommendation for implementation [9].

Examples of participatory ergonomics projects for MSDs

In 1994, Richardson and Hignett [20] discussed the use of PE in risk-management projects for MSDs. They summarized by saying that 'participatory ergonomics shows promise as an approach which could be used to evaluate changes in understanding and behaviour of people at work as far as risk management is concerned'. Since 1994, PE strategies have been used to address MSDs in a wide range of industries. The rest of this review will give brief summaries about some of these projects.

Participatory projects led by occupational health teams

Three examples were found where the PE projects for MSDs were directly led by occupational health (OH) teams in Canada and Japan. The first [21] reported an OH-led initiative, which was successful in improving communication between the stakeholders, management and OH team, with the result that (a) difficulties during the intervention programme were more readily identified, and (b) corrections were more easily brought in to ensure effective actions. The second Canadian example [22] used PE for a return-to-work programme for workers with subacute low back pain. They found that there was a good implementation rate for recommendations to modify the work demands to better match the workers' reduced capacity. The third example is from Japan [23], where the occupational physician at a steel mill generally took the lead in planning and implementing ergonomic measures, but for the PE programme this expert role was modified to foster worker participation. It was found that many successful improvements were achieved using this approach, without interrupting the work process, and there was also an increase in productivity.

Health care

Hignett reported on a systematic review looking at the range of interventions used to reduce musculoskeletal injuries associated with patient handling tasks [24]. It was found that the best results were obtained when multifactor intervention strategies included worker participation. The review allocated a quality appraisal score for each paper and then ranked the successful intervention strategies. The most successful strategies involved changes in work organization, working practices and the design of the working environment.

Evanoff *et al.* [25] reported a PE project that was carried out with hospital orderlies to see if direct worker participation in problem-solving would improve job satisfaction, injury rates, lost time and musculoskeletal symptoms. The intervention was evaluated using the OSHA 200 log, workers compensation insurance records; self-administered surveys of workers at 1, 7 and 15 months. They found a decrease in risks of work injury, with a reduction in the relative risk of 50%, for both OSHA 200 log and injury rate as well as a reduction in total days lost. The survey found a large and statistically significant reduction in the proportion of employees with musculoskeletal symptoms.

Fragala and Santamaria [26] described an intervention involving all staff at the hospital over a 3 year period, which used a four-step approach: (1) risk identification and assessment; (2) risk analysis; (3) formulating recommendations; and (4) implementation. The results showed an overall reduction of 48% in patient transfer incidents, a 67% reduction in lost work days, and costs reduced by 32% in the 1st year and 44% in the 2nd year.

Hignett [27] gave retrospective information about a 5 year ergonomics intervention programme that used a risk-management approach including PE to tackle musculoskeletal and manual handling problems. The results showed 36% reduction in musculoskeletal sickness absence; 33% reduction in manual handling incidents; and an increase in completed risk actions from 33 to 76% over the 5 years.

Pohjonen *et al.* [28] described an investigation into the effects and feasibility of a 12 month ergonomic intervention on work content and load in home care work. Various ergonomic measures were included that were designed and implemented as part of a participatory approach based on teamwork and group problem-solving within the work unit. The ergonomic measures improved both physical and mental work content and working conditions, and prevented the decline of work ability in the intervention group.

Estryn-Behar *et al.* [29] used a PE methodology for the conception of a new hospital laboratory. A number of different analyses (activity analysis of seven professional groups, space analysis, noise map and lighting map) were conducted to provide information for discussion at three workshops. The workers were able to plan a new space layout, which would be more practical for their work. This was tested with a 3-D scale model to give every worker the opportunity to modify the model. The final layout produced an improved functional distribution of the available space.

Military

Rice *et al.* [30] described a macro-ergonomics systems approach to tackle the high rate of musculoskeletal injuries occurring among a group of military personnel in the US army. This enabled the maximum participation of individuals from all levels of the command structure, e.g. the commanders, drill sergeants and non-commissioned officer instructors (cadres). The programme focussed on (1) describing the MSDs (types, causes, rates and predictors), (2) providing information on injuries to the command structure and (3) assisting the command to develop methods to control (or reduce) injuries and lost or restricted time due to MSDs. The control methods included reviewing technical (equipment, tools, workplace and environmental design), social (job design, training culture, management style and communication) and policy (regulations, written guidance) factors. They monitored the success of the program over 18 months by looking at the number of meetings and content of minutes. One of the useful outputs was the development of a standard operating procedure for conducting physical training, including information about injury control. This included a set of screening questions which drill sergeants could use to identify new recruits most at risk of injury.

Manufacturing

Liker *et al.* [31] compared and contrasted PE programmes in two US and two Japanese manufacturing plants. All four programmes focussed on the redesign of repetitive manufacturing jobs to reduce physical stress on workers. The programmes were successful in making significant numbers of job changes in both countries, but there were some differences in the structure and process of the participation. In the Japanese cases, participation was a carefully controlled process using quality circles. In the USA, multi-level task forces were formed that were given high levels of autonomy and made group decisions. Both programmes were effective suggesting that different models for PE may be needed in different cultures.

Halpern and Dawson [32] designed and implemented a PE programme to control and reduce workers' compensation costs for sewing machine operators at an automobile products manufacturing company. The programme had three basic components; (1) organization, (2) ergonomics methods and tools and (3) job design concepts. A management steering committee was set up and chaired by the vice president, with membership from the engineering manager, plant manager, safety director and a consultant ergonomist. A second committee included operational staff, maintenance personnel and supervisors. A further committee in the human resources department commenced a parallel initiative to control the severity of injuries and illnesses by developing improved programmes for medical intervention and case management. The intervention programme included task analysis for a set of six sewing jobs resulting in micro workstation redesign, e.g. sitting/standing work options, electrically adjustable height sewing tables to improve line of sight, forearm supports, shaped and padded edge workstations, redesign of the foot pedal, a machine guide and a changed scissor design. Macro changes included a review of the process flow to include mini breaks (and a stretching regime) and an empirical review to design new products for ease of manufacturability and new production processes based on ergonomic principles. Over a 4 year period, the number of MSD claims reduced by approximately 85% with an overall reduction in compensation costs by approximately 42%.

St Vincent *et al.* [33] aimed to implement and validate a PE process in two industries in the electrical sector. Joint ergonomics groups (workers and technical representatives) were given initial training and analysed several working situations resulting in 50 implemented proposals. These included a review of the workflow (movement of materials, the introduction of carts, pallet raisers, etc.), a redesign of the workstations (height, seating, etc.), purchase of new tools and the installation of balance systems for existing tools, automation of some operations, and increasing the work cycle to give the operator more time to complete the task. In three of the task areas, a 78% reduction in risk factors was observed, for example, a reduction in the postural stress, force requirements or mechanical stresses.

Mairiaux and Vandoorne [34] described a project that used a risk-assessment tool during a participatory approach of prevention of low back pain in a machine tool workshop (mechanics and maintenance workers). They compared the use of the tool as either a self-assessment or as a group assessment. They suggested that collective thinking (group assessment) with the support of an ergonomic expert, was a fundamental element in the development of a more autonomous management attitude by the workers.

Laitinen *et al.* [35] used a participatory programme to manage the problem of high musculoskeletal sickness absence in a metal workshop of the Finnish state railway company. The participatory programme had four phases, with each phase lasting about 6 months. The interventions included weekly audits and technical changes such as specially designed tool carts and waste containers, racks for lifting devices and transport carts for components. The results included a significant improvement in the performance level for the changes in working habits (as recorded on the observation charts). A reduction of 25% in absenteeism was recorded over a 3 year period with a significant improvement in the psychosocial work environment (support, solidarity and cooperation) for three of the four areas. They concluded that it was possible to induce favourable changes in psychosocial conditions and industrial relations by focussing on technical and physical improvements at a workplace and that a participatory process producing many small, but highly visible changes was a fast and inexpensive method for workplace development.

Production and processing plants

Kuorinka and Patry [36] tackled the problem of rising numbers of cumulative trauma disorders in a poultry processing plant by establishing a PE project to look at the biomechanical factors, production process, work organization, and the socio-economic context of the system. The group included employer and local labour union representatives as well as ergonomists, physicians, an engineer and a hygienist. The project enhanced communication and understanding between workers and management and the company realized substantial savings in injury compensation costs (no detail given).

Moore and Garg [37] evaluated the effectiveness of a corporate ergonomics programme that used a participatory approach to solve problems related to musculoskeletal hazards in a meat processing plant. The programme included: (1) workplace analysis using a safety and ergonomics survey, (2) hazard correction, prevention and control, e.g. purchase of deboning machines to replace manual deboning with knives, the invention of automatic hog splitters and bacon comb lifters, (3) medical management, with an increase in the availability of first aid and nearby medical care and (4) training and education on safe work methods and symptoms of MSDs. Twelve months after implementation, there was an increase in the crude incidence rate but a significant decrease in the percentage of recorded disorders related to musculoskeletal risk factors of 37% in the same time period and a 73% reduction in the per capita annual workers' compensation costs.

Bellemare *et al.* [38] described a project management approach for PE in two aluminium plants (with between 300 and 564 workers, respectively) as part of an MSD prevention programme. The programme was conducted over 2 years and was supported by a team of five ergonomists. Phase one involved selecting situations where there was a risk of MSD and forming teams (3–6 people) to prepare a diagnosis of the key elements underlying the risk factors [39]. The second phase utilized the teams to list corrective actions required to reduce the risk factors and then convert these into projects for change, resulting in 40 projects. Most of the change projects were of medium costs (CAN $5000–35 000) and concerned with equipment, resulting in the purchase and installation of equipment, modifications to existing equipment, redesigning equipment. Sixteen of 23 equipment projects (70%) were implemented.

Maciel [40] reported a participatory programme in the winding section of a synthetic fibre section of a chemical plant, which was set up to tackle the problem of increasing repetitive strain injuries that were affecting approximately 10% of the workforce. After a 4 month period, there was a statistically significant reduction in pain complaints, with a concurrent improvement in job satisfaction, operator productivity, quality of cones and amount of residual fibre. The model for participation was extended with the introduction of improvement groups to review other problems in the plant.

Lanoie and Tavernas [41] presented a cost benefit analysis of a PE programme for back-related disorders of packers at a warehouse of the Société des Alcools du Québec, which distributed wine and spirits in Quebec, Canada. Six principal problems were addressed as a result of the recommendations made by the joint working committee, mostly relating to the design and provision of equipment including an automatic pallet distributor, new pallet trucks, automatic pallet wrapper and the redesign of truck seats and gloves. A saving of $187 700 over the 5 year period was calculated based on the reduction in lost time and costs of recommended changes.

Service industries

Mansfield and Armstrong [42] described an ergonomics programme to control the risk of musculoskeletal disorders at the Library of Congress, Washington, DC, USA. The programme framework was led from the upper management through a plan of health and risk factor surveillance, interventions and training. The interventions included job analyses and equipment provision, for example VDU workstation modifications, trolleys, seating, anti-fatigue matting, etc. Comparative costs were documented, with $108 000 being spent in 1994–1995 on training and consulting services and $510 000 on the interventions. This was considerably less than the cost of workers' compensation claims at approximately $1 970 000.

Vink *et al.* [11] reported a project that aimed to reduce the physical (especially neck and shoulder complaints) and mental workload for office workers at the Dutch Department of Salary Records. Workers put forward suggestions that were tested systematically prior to implementation. The solutions included recommendations for optimal seat and desk heights, provision of a document holder, a back/knee support and adjustments to the screen position. A drawback of the process was the time required to implement change (12 months).

Nagamachi [43] described the redesign of a production line at an air-conditioner production plant using a PE strategy in order to (a) diagnose the postural problems and (b) produce recommendations for improvements. The changes included the redesign and provision of equipment including a hoist, monorail, table lift and auto-carrier. Most of the bad working postures, based on heart rate, relative metabolic rate and subjective evaluation of work load, were eliminated and a 25% increment in productivity was recorded.

Haims and Carayon [44] presented a case study of an implementation of a PE programme in a public service agency. There were five main stages of the programme, including training, mission and purpose development, evaluation of the work environment, interventions (physical workstation adjustments) and planning for the future. A reduction in MSD was recorded.

Construction

De Jong and Vink [45] evaluated a participatory approach for reducing musculoskeletal workload in installation, in construction and maintenance work. Participation was achieved through a number of methods including postal bulletins, working groups, and management and staff groups. Problem-solving was iterative with more than one step to ensure that the recommendations were feasible, achievable and efficient. There were measured reductions in physical workload, for example, a reduction from 34 to 6% in the time spent lifting/carrying. The solutions included a fold-out bench in the van, a seat for kneeling or squatting work, and new devices for reel replacement and transportation of heavy switch panels. The same authors reported a project that involved glaziers from three medium-sized companies in a project to reduce their physical workload [46]. There was a strong relation between the size of the company and the number of solutions implemented. The outcome was the development of a set of solutions which were evaluated after 12 months across 2050 companies. Of the companies that had implemented the solutions, 91% reported a reduction in the physical load over the 12 month period of the programme; however, this did not then lead to a measurable reduction in sick leave.

De Looze *et al.* [47] summarized seven cases using participatory approaches to reduce physical load on scaffolders, bricklayers, bricklayers' assistants and roof workers. A number of solutions were implemented as part of the project, including pallet trucks, electric winches, mechanical car hoists for raising window panes, crane attachments (pincer devices) to transport bricks and a new screwing device for roof workers. In all the cases, the physical load was measured (using heart rate monitors, NIOSH equation, spinal compression, etc.) and reductions reported, e.g. total holding time, high-risk postures. Strong management commitment and worker participation were given as prerequisites for all the projects.

Transport

Robertson [48] described two case studies in aviation maintenance operations that aimed to reduce human errors, increase safety and improve crew coordination and communication. A PE training programme was used and the overall results demonstrated a positive and significant effect on attitudes (command responsibility, communication and coordination and recognizing stressor effects), behaviour (a better listener, more aware of others, having more daily meetings to solve problems) and organizational performance (aircraft safety, personal safety, on-time maintenance).

Nagamachi [44] reported on the successful use of PE approaches in two Japanese industries. The projects used PE mostly in conjunction with quality circles to look at monotonous jobs in the car industry. A number of quality circles were set up to discuss the issues and decided that the largest job satisfaction would come from job enrichment so a one-man production system was set up whereby each worker engaged in assembling a whole passenger car. The productivity increased 100%. They also looked at big truck assembly. Quality circles were set up to address particular problems with the aim of decreasing accidents, e.g. manual handling problems when mounting a propeller-shaft. The solutions included rotating the truck body frame so that the propeller-shaft could be mounted from the top rather than the bottom. One female worker rather than four male workers could achieve the final process and there was a higher quality of product without back injuries.

Discussion and conclusion

Most of the projects included in this review have both macro and micro dimensions and involved many levels of staff. They fit well with the definition of PE, given by Wilson [5], with workers being given the opportunity and power to use their knowledge to address ergonomic problems relating to their own working activities. PE programmes can have many factors (as identified in the PE framework) and some will be more in evidence than others depending on the industry, problem being addressed and even geographical locality. In the USA, participatory approaches have been used more at the macro level, whereas in Europe there has been a much wider application of this approach. These cultural differences need to be addressed with culturally sensitive approaches, but the fundamentals of a participatory approach to tackle MSDs transcends these differences and offers real possibilities to achieve improvements. Although a wide range of ergonomic tools can be used within a participatory framework it is usual to see a progression, with the expert ergonomist facilitating the process from problem identification and definition through to the testing of solutions. The steps may include problem analysis using both quantitative and qualitative methods to facilitate the overall process and data collection in the real world setting.

The complexity of PE projects is shown in the scope of examples given here. Although most have a micro component, the project is always underpinned by a macro framework that usually includes the top four dimensions from the PE framework. The structure for decision-making is defined for the mixed group of participants, with a clear remit facilitated by ergonomic expertise.

It is often difficult to evaluate real world changes due to organization restructuring that often accompanies this type of participatory project. However, this should not be seen as an excuse, rather again as a challenge to design robust evaluation measures into PE projects in order to generate future case studies.

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