Ergonomic Interventions for Reducing Musculoskeletal Disorders:

An Overview, Related Issues and Future Directions

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Summary

In most industrialized countries, the costs of compensation for musculoskeletal disorders account for at least one half of all workers compensation costs and recent reviews have reaffirmed that a strong work-related component exists for many upper limb and low back pain cases. A combination of physical, psychological, and psychophysical workplace risk factors have been documented. Risk factors for the development of low back pain include (moderately) flexed, laterally bent or twisted trunk postures, high forces on the hands, high one time or accumulated forces on the spine, and vibration. Similar workplace physical risk factors are associated with high levels of musculoskeletal disorders in the neck, shoulders and arms. Physical risk factors such as high forces, high repetition, working with arms overhead, long term static postures, local contact forces and vibration are commonly identified. Psychological risk factors are found regardless of whether the problem is upper limb, low back or elsewhere. They include perceptions of low control and poor workplace social environment, and perceptions of high physical demands whether measured to be high or not. There is conflicting evidence on the role of job satisfaction as a risk factor. Reduction of these risk factors is the goal of most preventive approaches.

The work-related portion of the injuries and resulting disability is potentially preventable and it is important to identify interventions for reducing work-related musculoskeletal disorders (WMSD). There are many approaches to intervening in the workplace to reduce initial incidence (primary prevention) and disability (secondary prevention). For example workstation design changes, employee training, back schools, wrist splints and back belts, job rotatation and stress management are commonly used approaches. The purpose of this Chapter is to review the evidence for (or against) the utility of ergonomic interventions. The Chapter will not be an epidemiological review of intervention studies but, rather, it will map out the issues in intervention to prevent musculoskeletal disorders, summarize the literature which bears upon these issues and suggest issues that must be addressed in the future.

Ergonomic interventions are commonly classified as engineering, administrative or behavioural/ personal. Rigorous evaluation of effectiveness of interventions is, however, difficult for methodological and organizational reasons and research reported on many interventions does not reach usually accepted levels of scientific quality. Despite this, the following conclusions appear warranted: For primary prevention, engineering interventions appear to reduce exposure to risk factors (efficacy) but the literature does not have enough studies which have applied these changes to sufficiently large numbers of workers to determine their effectiveness unequivocally. Similar comments apply to administrative interventions. There are a number of more robust experimental designs used in the assessment of behavioural and personal interventions. There is some, but limited, evidence for the effectiveness of exercise for reduction of LBP even though variables such as low muscular strength or body joint flexibility have not been convincingly shown to be risk factors, a preponderance of studies showing little effectiveness of education and contradictory evidence for personal equipment such as back belts. For secondary prevention there is some evidence that engineering and administrative changes in conjunction with managed care give the best outcomes.

Among the issues that need to be addressed to inform directions for future research are:

1. The majority of efforts over the last two decades have been devoted to determining the work-relatedness of musculosketal disorders. In these authors opinion, the conclusion to be drawn is that there is moderate to strong evidence that many musculoskeletal disorders have a substantial work-related component. This is not to imply that thresholds and dose-response relationships of risk factors are clear. They need continued research. However, it is necessary to add to the research agenda, good studies on the development, implementation and evaluation of the effectiveness of various approaches to interventions to reduce risk of injury, social and monetary costs. There is some research evidence and many case studies that suggest that ergonomic interventions reduce risk and cost of occupational injury but the study designs have generally been weak. Furthermore we suggest that the specific research question(s), the experimental design, the plan for data acquisition, interpretation and dissemination must be planned with the potential user groups if utilization of results, even at a local level, is to be realized.

2. Determining risk factors for WMSD has been mainly a researcher lead effort. It is not clear that the next phase of the effort, prevention of work related musculoskeletal disorders, can continue in the same way because of the difficulty of outsiders intervening in the business of the workplace. However, in the experience of the authors, it is difficult to engage management in research studies (as opposed to service delivery) in their plants. Indeed, their understandable view is that they produce goods or services and they are not in the business of doing research. Without workplace involvement, advancing knowledge about what interventions work and which do not and why, cannot be done.

Scope of Review and Rationale

The costs of compensation for musculoskeletal disorders accounts for more than one half of all workers' compensation costs (Institute for Work & Health, Toronto). Recent reviews have reaffirmed that a strong work-related component exists for many upper limb and low back pain cases (Hagberg et al., 1995, NIOSH 1997). The work-related portion of the injuries and resulting disability is potentially preventable and it is important to identify ergonomic interventions that are effective in reducing both the incidence of initial work-related musculoskeletal disorders (WMSD) and/or reducing disability from injuries, their personal costs and the monetary costs associated with them (Frank et al., 1997). This chapter will focus on evidence for the utility of "ergonomic interventions" in the reduction of WMSD or disability arising from them.

We do not intend to be pedantic about definitions; however, we feel that it is important to note that the concept of ergonomics referred to throughout this chapter is much broader than simply physical factors in the workplace. The International Ergonomics Association, the body that represents most people involved in the field or ergonomics or human factors, explains that ergonomics is the process of designing, modifying or organizing tools, materials, equipment, work spaces, tasks, jobs, products, systems and environments to match psychological, social, anatomical, biomechanical and physiological abilities, needs and limitations of people. Thus, the scope of ergonomics or human factors, (we will use the terms synonymously), includes physical, cognitive, social and organizational aspects of work. Moreover, ergonomics includes interventions aimed at improving work at both the level of individuals (microergonomics) and at the level of work organization (macroergonomics). Clearly, these levels interact with each other. The objectives of ergonomics are to improve the quality of the product or service provided by the company, worker productivity and the quality of working life of employees by designing or modifying work so that there is minimization of risk of injury, fatigue and error. Ergonomics focuses on people in the process of production, maintenance and use of goods or services provided by a company.

Factors from all four areas that affect and effect work and the workforce, physical, cognitive, social and organizational, have been shown to be related to the development of musculoskeletal disorders; therefore, interventions which change any of these four types of factors are of potential use to reduce musculoskeletal disorders. Table 1 illustates some ways by which interventions have been characterized. Irrespective of the taxonomy chosen, interventions are normally aimed at reducing or eliminating risk factors for injury. Therefore, it is essential that there is as clear an understanding as possible of what the risk factors for WMSD are.

Table 1 — Taxonomy of Interventions to Reduce WMSD

Workplace Determinants of Health	**A**	**B**	**C**
Organizational Structure and Environment at Firm or Unit Level	Macro-ergonomics	Administrative	Organizational Structure
Job/Task Factors	Micro-ergonomics	Engineering	Interpersonal Relations
Individual Factors	Personal Protective Equipment and Training	Personal Protective, Training and Behaviourial	Individual

Risk Factors for WMSD

On the basis of a number of recent critical reviews of the literature (Burdorf, 1992; Winkel and Mathiassen, 1994; Hagberg et al., 1995; NIOSH,1997; Punnett and Bergqvist,1997) many types of musculoskeleletal disorders have substantial work-related component. This is especially true where there is a high level of exposure and where there are combinations of adverse conditions, e.g. lifting loads with the arms outstretched at a high frequency is stressful for the shoulder region.

There is strong evidence that low back disorders are associated with lifting, high exertion and awkward back postures (e.g. Punnett et al.,1991; Marras et al.,1993). Studies using objective measures to quantify work exposures, worker by worker, generally show stronger relationships than studies which used less precise methods such as job titles applied to many workers in a group. For example, a recent study using an extensive battery of both psychosocial and biomechanical exposure measures found that both types of variables were important, independent contributors to the reporting of low back pain in the automobile assembly industry. Specifically, peak and cumulative forces on the spine, peak forces on the hands, trunk postures, and perceptions of a poor work social environment, low decision latitude, good co-worker support, job satisfaction and high physical demands were all important, independent risk factors for reporting low back pain (Kerr, 1998; Norman et al., 1998). This study provided consistent evidence of an association between workplace biomechanical factors and LBP and independent, though less consistent contributions for psychosocial factors. These observations were different from those reported by Bigos, et al., (1991) who found that only job dissatisfaction was significant. However, their estimates of physical demands were done only at a group level or by job title. Whole body vibration has also been found to be strongly related to low back pain.

For the neck and shoulder there is strong evidence that non-neutral posture, especially overhead work, as well as high forces and high frequency movements are associated with development of disorders in the region. For the arm, combinations of forceful actions awkward postures and high frequency movements are associated with the development of carpal tunnel syndrome and tendinitis.

These findings typically come from industrial work activities. There is also a growing recognition that office tasks, especially those associated with Visual Display Terminal (VDT) can lead to musculoskeletal disorders. Disorders of the hand and wrist appear to be related to long term use of the keyboard; the mechanism appears to be repetitive finger motion and sustained muscle activity in the forearm. For many body areas there is good to strong evidence that work exposures are associated with the development of injury and that the relative risk of certain work exposures is high; this was true for shoulder and hand/wrist tendinitis, low back pain, carpal tunnel syndrome, hypothenar hammer syndrome, tension neck syndrome as well as localized musculoskeletal symptoms i.e. pain. Plausible biological mechanisms for these risk factors to result in disorders of the musculoskeletal system have been proposed. Our best evidence points to a complex interaction of physical, psychosocial and individual factors in the production of musculoskeletal disorders at work.

It should be noted that while the literature is clear on the main risk factors for injury, details of mechanism of injury and injury threshold values are often unclear. For example, recent epidemiological studies have indicated that increasing time using a visual display terminal (VDT) leads to increasing risk of developing musculoskeletal disorders of the shoulders and arm (Punnett and Bergqvist, 1997). It has also recently been epidemiologcially documented that cumulative compressive force on the spine is an independent risk factor for LBP (Kerr, 1998; Norman et al., 1998). However, it is not possible to reduce the time using VDT to zero; data must still be entered. Nor is it possible to reduce cumulative compression on the spine to zero. The spine is in some level of compression while just sitting or standing. Until there is a better understanding of tolerable durations or rates of working with VDTs or loading the low back and, in general, how time-related factors cause tissue damage it is difficult to understand exactly how long term VDT use elevates injury risk, and it is difficult to produce effective mice, keyboards, workschedules or job designs.

Ergonomic Interventions

WMSDs are now recognised to have multiple risk factors spanning the individual, the interpersonal, the physical environment and the organization of work. Investigators from different disciplinary backgrounds, each with their own taxonomy, have approached interventions in a variety of ways. We shall use the terms, engineering, administrative and behavioural interventions. Of course in any situation, multiple interventions may be made simultaneously or sequentially. The review papers by Goldenhar and Schulte, 1994, Grant et al., 1995 and Zwerling et al., 1997, include many examples of interventions.

Engineering interventions are engineered or physical manipulations of hazards or routes of exposure to physical hazards. Typical examples may be the provision of lift tables to prevent lifting from ground level, or adjustable office equipment. Administrative interventions concentrate on changing the duties or the design of the job such as the introduction of job rotation, enlargement, work cells, or policies, for example requiring at least two persons to lift patients in a hospital. Behavioural interventions focus on the individual worker's behaviours or capacity. A behavioural (or personal) intervention may focus on increasing fitness or strength, on stress reduction workshops, on improving work methods. Requiring the use of personal protective equipment is a further option and is commonly used in safety and industrial hygeine.

Let us take the example of one task undertaken by custodial staff. Emptying mop buckets full of water into a sink is a high risk activity because of the magnitude of the risk factors; high trunk loads and lifting from floor level. In addition, because of the sometimes cramped situations in custodial closets, it is likely that twisted and laterally bent postures are simultaneously present. The presence of high spinal loads and non-optimal postures to support them is central to assessing the task as high risk despite the relatively low frequency of lifting.

Engineering changes would modify the custodian's job of emptying mop buckets, perhaps by installing floor level drains to allow the bucket to be tipped rather than lifted (this will likely not solve the problem as the work is still performed in a bent over posture), adding a drain valve or tap, designing a bucket that holds much less water or installing a powered lift to empty the bucket (unlikely in this situation but common in industrial settings). Note that some of these eliminate the risk factors (emptying with a tap or the powered emptying) while others reduce the risk factors (the smaller bucket).

Administrative changes for emptying the mop bucket could include designating the job "non-essential" to the job and having a co-worker perform it, requiring that full mop buckets be emptied by two people, only performing the task alternate weeks or requiring that mop buckets only be filled half full of water. As with engineering changes, some of these may be effective in reducing the risk to the given worker (having a co-worker perform the task) but the risk may now accrue to another worker.

Behavioural and personal changes operate by attempting to reduce the hazardous effects of the risk factor by training in correct technique (back schools) or improving the capacity of the worker (fitness and exercise programs or stress management programs). Personal Protective Equipment is intended to work by putting a barrier in place between the hazard and the person (padded gloves if the hand is used as a hammer or holds vibrating tools). Some approaches, such as back belts, are suggested as combining a number of these strategies.

The main difficulty with administrative and behavioral changes and personal protective equipment is that they may not be adhered to or used; a rush job will likely mean that the worker cannot wait for a co-worker to help, does not tighten or wear the back belt, or cannot use the educational information on proper manual handling in their workplace. Due to a change in the worker or the supervisor, the administrative control may be forgotten. Engineering changes, on the other hand, tend to be more permanent, affect all workers on that job and are unlikely to be bypassed under time pressure. For these reasons engineering changes are usually recommended as a first approach and administrative controls are recommended only if job design changes cannot be instituted or further risk reduction is required. The last resort should be behavioral and personal protective equipment changes.

Efficacy, Effectiveness and Cost-effectiveness

There are many possible outcomes by which ergonomic interventions may be evaluated (see Table 2). Classically these range from *efficacy* determined under ideal conditions on selected groups in a laboratory or field setting, through *effectiveness* measured under field conditions on larger groups, to *cost-effectiveness or cost-benefit* studies. Intermediate outcomes or descriptions of implementation such as the *intensity* of the intervention (e.g. how many hours of training) or the *compliance* of people with the interventions are known as *process measures* and are important in understanding how the intervention did or did not affect the outcome of interest. An example may serve to illustrate these issues.

Table 2 — Assessing Intervention Effects Aimed at Reducing WMSD, Necessary Conditions for Success of Intervention and Evaluation of Interventions

	Action/Indicator/ Outcome	Some Necessary Conditions for Success of Intervention and Evaluation of Interventions	Example 1 Engineering: Introduction of Lift Assists to Reduce Patient Lifting in Health Care	Example 2 Administrative: Introduction of Job Rotation in an Assembly Line Operation	Example 3 Training: Anatomy and "Proper Lifting Technique"
Efficacy	Short term Laboratory or classroom changes in response eg., EMG, discomfort, knowledge or performance	Intervention must reduce exposure to hazards, or increase the person's capacity to tolerate them	Peak loads on the spine were reduced using mock-up with healthy volunteer "patients"	The amount of time spent with the arms extended in front of the body when rotating between selected tasks	Increase in knowledge or skill must occur

Table 2 — Assessing Intervention Effects Aimed at Reducing WMSD, Necessary Conditions for Success of Intervention and Evaluation of Interventions — (Continued)

Effectiveness	Very short term (~1 day) field changes in response eg., strength, EMG, discomfort, emotional strain or performance	Intervention must transfer to the field	Loads when handling patients under normal operating conditions must be reduced as demonstrated by, for example, EMG of muscle	A rotation scheme must be implemented that allows rotation between tasks with different demands as measured for example, with EMG or posture recording	Knowledge must result in behaviour changes. This may require engineering or administrative changes to the workplace
	Short term (~4 weeks) field response eg., strength, EMG, discomfort emotional strain or performance	Intervention must be of sufficient intensity to produce an effect	Use of the lifting assist must continue under in order to reduce exposure	Rotation must be maintained with rotation among tasks with different demands	Newcomers must be trained to maintain intensity of intervention
	Long term (+1 year) changes in reported MSD, pain, performance, emotional strain, quality, scrap etc.	Reduced exposure leads to reduced incidence of MSD. Intervention must be sustainable with high intensity and compliance. Outcomes must be measured in treatment group and preferably a comparision group			
Cost-Benefit	Long term (+1 year) changes in cost of MSD, performance, quality, scrap etc. and costs associated with intervention	Costs must be assigned to both health outcomes (Compensation and Sickness Absence costs) If the treatment group is small or many have disorder's at the start of the study, effects may take a number of years for effect to become detectable even if the intervention is effective			

A small company had two back cases in a department with heavy lifting within one year. Powered lifting asists were introduced as an engineering intervention. One year later no reductions in the costs associated with back claims were found. The intervention was assessed as a failure. A review of the specifications of the lift assists showed that in efficacy tests in the laboratory the hoists reduced low back loads for the weights of interest. Feedback from supervsiors and workers, however, determined that many people in the department were not familiaar with the use of the lift assists and, as a result, the compliance with using them was low. In addition, breakdowns meant that they were not available much of the time . These process measures indicated that both the intensity of the intervention and compliance were low. This may have lead to poor effectiveness of the intervention on the plant floor. A measure of the number back strains from WCB claims and the first aid logs would have been useful in determining effectiveness. Upon review of the cost data it was determined that most of the costs were due to an injury which occurred in the previous year. Cost data were also deemed to be unstable due to the small size of the company and the limited follow up time. In summary, the original conclusion, “no effect”, was not warranted. This example and the other examples in Table 2 show the challenges facing both the introduction of interventions for reduction of WMSD and for their evaluation.

Study Designs for the Evaluation Ergonomic Interventions

There are a number of experimental designs available to study the effectiveness of ergonomic interventions. These include pre-post designs, pre-post designs with control groups, and randomized controlled trials. As we progress down this list the designs allow a more unbiased assessment of the intervention’s effectiveness. Unfortunately, randomized control trials, although regarded as the “gold standard” in many fields, are expensive and difficult to conduct in field settings. Sound experimental designs are characterized by randomization of assignment of people or other units of analysis to control and treatment groups. Studies reported on the evaluation of interventions in the workplace are rarely able to comply with randomization criteria of good research and often use a measurement on the same group before intervention as a control, if there is any control group at all. The problem with this so-called “historical control group” is that changing conditions unrelated to the intervention, but which affect the outcome, can occur during the course of the intervention (e.g. change in the economy). A before/after experiment can not account for the effects of these changing conditions and the intervention my be credited with a change that it did not cause.

A sampling of recent reviews of interventions for reducing musculoskeletal disorders (WMSD), safety and mental health outcomes revealed two main threads. Firstly the literature catalogued the studies which had attempted to change employee relations, task requirements and organizational structures AND had an evaluation process (Kilbom 1988, Goldenhar and Schulte, 1994, Grant and Habes, 1995, Zwerling et al., 1997). Secondly, much of the literature noted the lack of rigorous design and evaluation methods used in the interventions reviewed and set out criteria for appropriate evaluation (Goldenhar and Schulte, 1994, 1996; Malmivaara, 1997). Alternatively, if they believed this rigour to be impractical, they recommended strategies for performing studies which, while not as methodologically strict, would inform best practice (Kilbom, 1988; Silverstein, 1987; Polanyi et al., 1996; Zwerling et al., 1997). The recommendation is a tiered approach whereby interventions would first be studied by simpler, cheaper and faster, but less statistically sound research approaches. Only those interventions which looked most promising would be tested with the most rigorous and expensive experimental design approaches.

Review of Literature on Ergonomic Interventions

The last five years have seen an increasing interest in documenting the effectiveness of interventions to prevent musculoskeletal disorders at the primary and secondary level. This is driven by the high costs of these disorders and the growing interest in regulatory approaches, e.g. British Columbia (WCB of B.C., 1998) and OSHA in the USA. This section is NOT an epidemiologic review of the intervention literature; there are a number of excellent recent papers on methodological issues in intervention research. Rather, it is a summary of the field of ergonomic intervention. The section will review engineering, administrative and personal interventions and then move to a discussion of how the changes might be made by considering systems interventions, and participatory approaches to change, a type of psychosocial intervention. The section ends by describing the few cost benefit studies that appear to be available on ergonomic interventions.

Engineering Interventions

There are literally hundreds of engineering interventions described in the scientific and lay literature; for example the National Safety Council (1982) lists a wide range of solutions (interventions) to occupational health and safety problems contributed by companies. Most appear to have anecdotal support from the contributing company but lack formal evaluation. Grant and Habes (1995) summarized twenty-four engineering interventions to reduce ergonomic risk factors for the low back and upper limbs. For example, Gallimore and Brown(1993) intervened to reduce visual fatigue and body discomfort in Visual Display Terminal users. Analysis indicated that awkward static work postures were contributing factors. VDT screens were fitted with a screen which moved the image further from the eye. This lead to reduced glare, and improved neck posture for bifocal wearers.

The majority of the evaluations were short term efficacy type studies. The reduction in exposure to risk factors (efficacy) was assessed by many means including postural improvement (most evaluations), reduced muscle activity, reduced tissue loads and reduced vibration. In a few studies performance, such as productivity and errors, was assessed. In almost all examples the intervention reduced exposure to risk factors.

A few engineering intervention studies have followed workers over longer time frames with endpoints such as musculoskeletal sick-leave. Aaras and Westgaard (1987) followed the workforce of a telephone manufacturing facility over eight years. The introduction of adjustable work surfaces, arm rests and other engineering changes to reduce postural load during assembly of wiring panels both reduced muscular demand on the shoulder region, as measured by electromyography, and musculoskeletal sick leave. Although the intervention was largely of an engineering nature, as is common in most situations, other co-interventions were occurring. As well, there was no comparison group to help control for other long term changes that occurred over the eight year project .

A recent study in a health care facility, although aimed at secondary prevention to prevent lost time resulting from low back pain, reported substantial reductions in the incidence of lost time claims, possibly resulting from spillover from ward where the interventions were made (Yassi et al 1995).

Administrative Interventions

Administrative interventions often change the duties of workers by job assignment changes or rotation or the break schedules. The concept of microbreaks, or frequent (every 10 minutes) short (30 second) breaks is advanced for workers in both industrial and office environments. These breaks may be either passive (sit or stand quietly) or active (combine the break with stretching or simple exercises). Studies in the field and laboratory indicate that the approach has merit in reducing discomfort. Genaidy et al., (1995) reported that four weeks of active microbreaks lead to a statistically significant reduction in perceived discomfort among 28 workers at a meatpacking plant. Henning at al., (1997) studied two sites where workers used computers and introduced microbreaks for a 4-6week period. The introduction of microbreaks did not lead to any improvement in productivity or well-being at one site but they reported that productivity, eye and leg comfort improved when the short breaks included stretching. These studies in office and food processing suggest that active microbreaks may be required to realize the benefits of breaks however longer term studies are not currently available.

Personal/Behavioural Interventions

This type of intervention is the best studied. This is probably because interventions such as education or personal protective equipment allow large scale and even randomized trials more easily than workplace equipment changes. Most of this research is focussed on back pain. The literature identifies three major types of interventions; education or "back schools", exercise, mechanical supports (wrist splints or "back belts"). Because of the specific nature of the device and the conflicting evidence for their effectiveness (Lahad et al., 1994, van Poppel et al., 1997), back supports will not be discussed further.

A smaller body of evaluation focusses on work methods training using peer group feedback, video or electromyographic feedback. For example Parenmark (1988) used electromyographic feedback to train work methods with low shoulder demand in newly hired and experienced assemblers. A control group was used in each case. A one year follow-up showed that the new hires trained by feedback had less musculoskeletal sick leave in the shoulder region but that the experienced workers had no statistically significant decrease. Smith and coworkers used a peer training process in the meat packing industry to improve work methods (Smith, 1994). In the following year a reduction in reported injuries was observed. However a pre-post design without a comparison group was used.

One of the better executed studies on back pain and exercise by Gundewall et al. (1993) studied 28 hospital workers who performed back specific exercises with a control group of 32 similar workers. The two groups were followed up for 13 months. The exercise group had less back pain complaints (53.9 vs 94.3) and less mean days lost from work (1.0 vs 4.84). The consensus of recent critical reviews are that exercise has some effect in the prevention of low back pain (Lahad et al., 1994; van Poppel et al., 1997).

Education for prevention of musculoskeletal disorders may be a short didactic presentation or a more comprehensive program. Content is typically organized around anatomy, risk factors and lifting technique or proper body mechanics. Many of the interventions which utilized education also included another component. For example in the study of Walsh and Schwartz (1990) evaluating back supports, one group also received a 1-hour educational program stressing lifting technique. A test showed that those who took the education program scored higher on low back pain knowledge. This indicated that the educational program was effective in increasing knowledge. On 6 month follow-up no difference from the control group in absenteeism was noted, however. Similar results were found in the study of Daltroy et al (1993) except that they also noted that despite the increased knowledge about low-back pain 2 1/2 years later, they did not detect changes in the work behaviours targetted by the program, such as postures of the arm and back. In this case the increased knowledge did not translate into changed behaviour with reduced physical exposures, perhaps for the reasons described before, time pressures, poor workplace layout etc. Overall, the reviews of Lahad et al., 1994 and van Poppel et al., 1997 found that there was not good evidence that education was effective in the prevention of low back pain.

Combined Interventions

Frequently multiple focus interventions are made simultaneously. For example Grant and Habes (1995) and Zwerling et al., (1997) described over thirty published studies where the effectiveness of a variety of control strategies in reducing musculoskeletal disorders and discomfort was evaluated. The studies were of widely different methodological quality and the results ranged from being ineffective, to being unable to evaluate the intervention to being effective. In almost all cases the interventions combined a number of approaches; engineering, administrative and personal. This makes identification of critical aspects of the intervention difficult. Kilbom (1988) summarizes that job redesign (engineering changes) are best, but as physical environment improves, work organizational and psychological factors become more important. These multiple interventions are not usually planned to take advantage of the interactions among the engineering, administrative and behavioural interventions. A systematic approach to intervention appears to be useful.

Systems Interventions

It is quickly apparent to all who do field research in workplaces that many interacting human factors are at play in issues of quality, productivity, health and safety. Combinations of biomechanical, psychological, and physiological factors operating at the level of the individual employee are clearly influenced by company organization, policies, production schedules, financial viability and a host of other factors that mould a work social climate or culture. Worker attitudes, behaviours, abilities and limitations undoubtedly feedback on, and modify the culture. Some of these interacting factors can be visualized in Figure 1. Hendrick (1991) and others advocate a systems approach to harmonizing the technical and personnel subsystems in an organization, an approach referred to as macroergonomics.

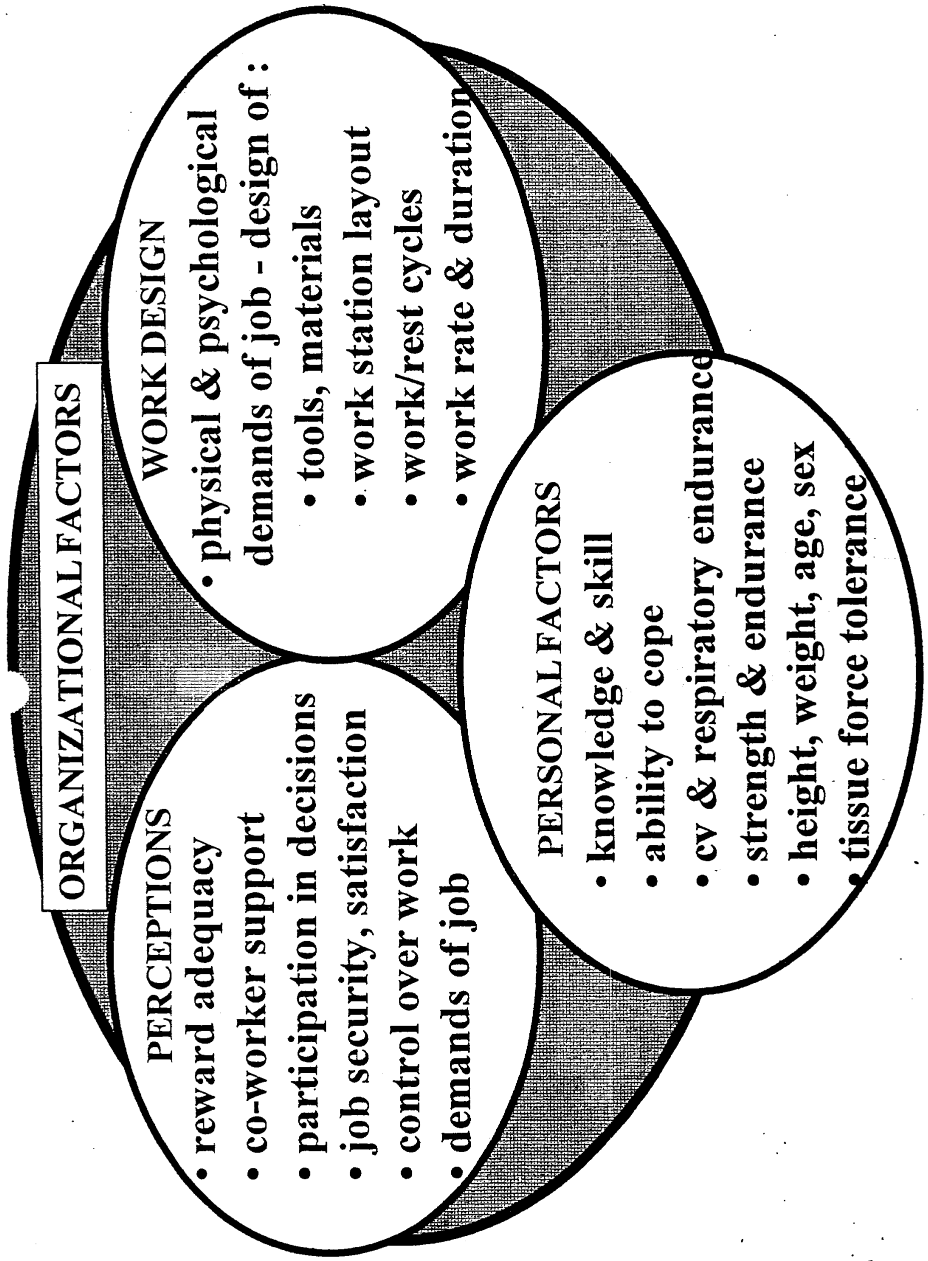

Figure 1. Personal characteristics of workers, their perceptions about their work and ergonomic aspects of the design of work are all superimposed on a background of workplace organizational factors and interact with each other to affect productivity and the quality of goods and services. Work design and personal factors are involved in the generation of injury and the interactions among all four factors affect decisions by a worker to report pain, go off work and whether or when to return to work.

Amongst the many issues of concern to a company are employee decisions to leave work because of work-related pain and when or whether the employee will return to work following pain-related absence. No single factor can be expected to predict decisions related to risk of pain-related injury absence. There are many articles that address the effects of the interactions of factors on job stress, mental and physical health and a number of models for intervention have been proposed that attempt to simultaneously account for the system of unitary and combined influences. The models are logical and possibly useful, but they all appear to be at the stage of hypothesis, not proven effectiveness.

For example, Smith and Carayon (1996) proposed a plausible, but not entirely new, systems model in which they, by admission, speculate that both psychological and physical stress perceived by video display terminal users can result in WMSD because of imbalances among elements in the work system. Their five elements include: technology; job/task design; work (social) environment; organization of work; the individual (at the centre). An adaptation of this model is found in Figure 2.

Imbalances among these elements, they suggest, result in adverse physical and psychological reactions that are expressed, for example, as direct injury to tissue, elevated muscular tension resulting in chronic fatigue and/or hormonal sensitization to pain because of psychological stress, inappropriate work methods as a result of low morale and indifference, etc. The imbalances are caused by deficiencies in one or a combination of the elements of the work system. These authors state (1996:36): "There currently is no scientific evidence or valid hypothetical biological mechanism that can logically define physical stressors as superordinate to work organization stressors in causing CTDs, or inversely, as subordinate to work organization stressors in causing CTDs." Our study on biomechanical and psychosocial risk factors for LBP supports this position (Kerr, 1998; Norman et al., 1998).

Smith (1997) proposes that interventions should start with organizational support, arguing that this increases motivation and feelings of security in the workforce, reduces stress and reduces resistance to change. Furthermore, he suggests that "employee participation" is an essential aspect of technology implementation. Indeed, there is an increasing advocacy of "participatory ergonomics" by ergonomists. It is useful to review some of the reports on "participatory ergonomics" and the state of evidence for the efficacy of this approach to intervention.

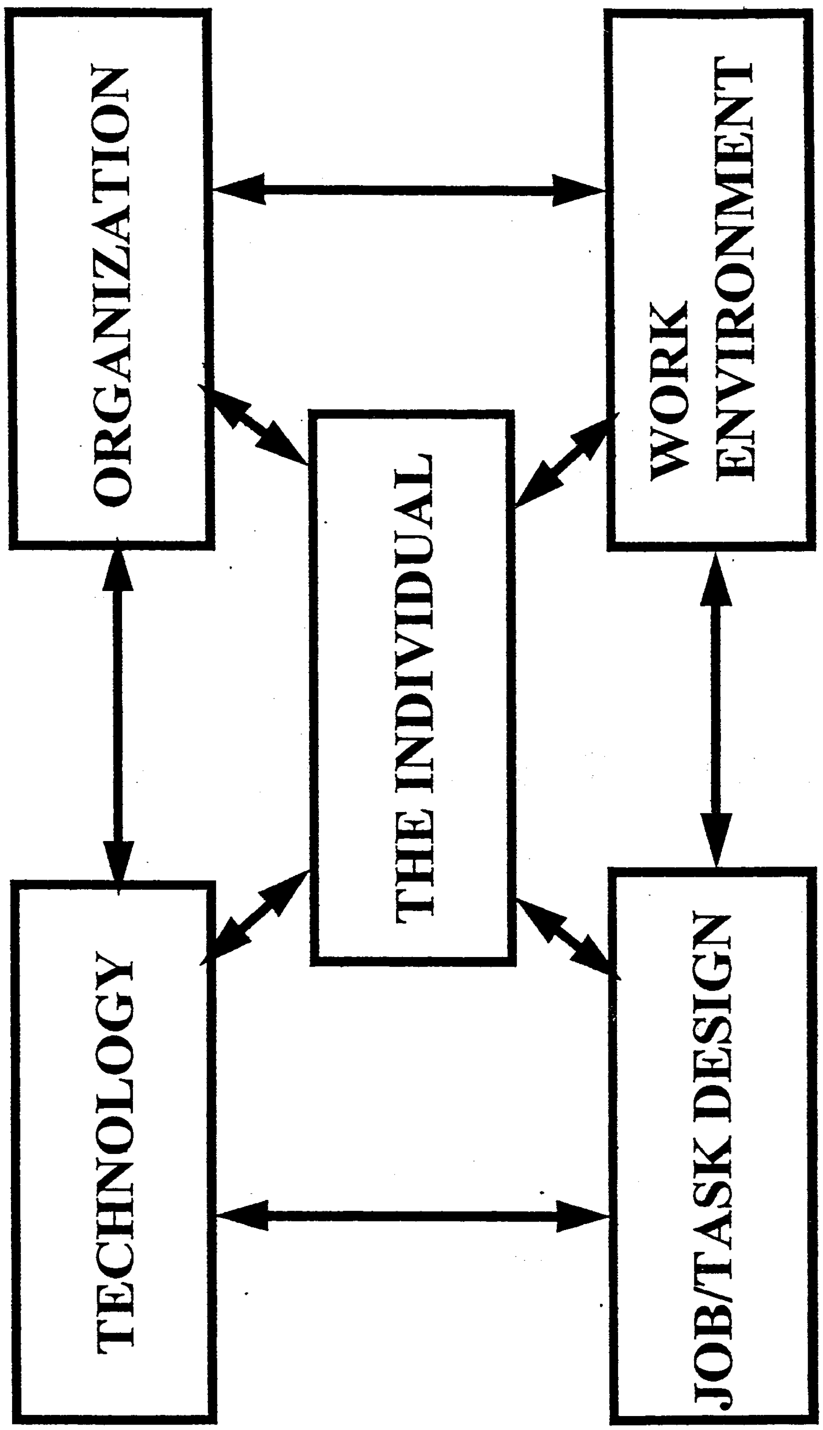

Figure 2. A model of the work system proposed by Smith and Carayon (1996). Imbalances in this system are proposed to lead to stress and strain responses caused by physical, ergonomic and psychological loads which are controlled positively or negatively by work organization.

Participatory Ergonomics: a Psychosocial Intervention Process and Intervention

Wilson (1995:1071) explains that participation within an ergonomics management program at work can be taken to be, "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." Kourinka (1997) defines participatory ergonomics as practical ergonomics with participation of the necessary actors in problem solving. The participation is not limited to worker participation but rather, includes all levels of the hierarchy with first-hand experience about the problem at hand. It may be formal or informal participation. Thus, it is a means of using an organization's experience to devise the best interventions, be they administrative, personal or engineering. Participatory interventions are also reported to result in improved communication among stakeholders that has positive results substantially beyond the issues at hand (Saari, 1992). Thus, participatory ergonomics is a psychosocial intervention in itself.

Vink, et al. (1992) commented that although many people had experience with participatory ergonomics at that time, the underlying theories and methods were not well developed. More recently, Kourinka (1997) has noted that the methodology in participatory ergonomics is not a solid body of knowledge based on a theoretical construct. It is merely a collection of structures and approaches which have shown their usefulness in the hands of a competent ergonomics practitioner. There are several models of participation. One is that workers participate fully in all aspects of the process of improving the working environment from problem identification, through to data gathering, analysis of information, solution invention or selection, implementation and evaluation. Advantages are stated to be that workers know their work best and worker generated solutions will facilitate acceptance. Disadvantages are that management is neither convinced nor committed to the process or the outcomes. An alternative form of intervention is that workers formulate solutions and experts make the final selection. This is reported to help solve both the problem of the threatened authority of management and the risk to labour members of the participating team of the recommendation for or implementation of unpopular or faulty solutions.

Several studies on participatory ergonomics have appeared in the scientific literature. However, a number of them are largely qualitative. Kourinka, et al., (1994) used a participatory process for the redesign of the front seat of police cars to determine if such a process would influence perceptions and create more realistic attitudes towards LBP. Two groups of police, 15 people with a history of significant LBP and 15 with no LBP met twice a week to develop design recommendations after they had received some instruction in the basics of the biomechanics of seating, back structure and related topics. The outcome was enthusiastic and committed participation by members of all groups but no differences between the LBP and no LBP groups in approach to the redesign process. The authors stated that they could not reject the hypothesis of changed attitudes towards LBP. The problem with the study is that it is entirely qualitative, minimizing the ability to test any hypothesis or to generalize findings about participatory ergonomics.

Moore and Garg (1996, 1997a, 1997b) reported that a participatory ergonomics program in the red meat packing industry, an industry with high incidence and severity of WMSD, resulted in high ratings of satisfaction with the process by the ergonomics team members in all aspects except "solution implementation". A participatory process had been in place for several years during which time 55 job modification had been implemented, but crude incidence and lost time rates had continued to grow. Perusal of data in the papers shows that there had also been an increase in line speed of hog processing from 625/hr to 762/hr since the beginning of the ergonomics program. The lessons learned from the study are that even job modifications may not permit substantial increases in work rate without penalty of increased WMSD. The authors themselves point out that the study was a demonstration project rather than an experimental project and, as such, the design was a "post-test only with non-equivalent groups", a quasi-experimental design. This weakness not-withstanding, the participatory outcome was considered successful. This is one of the more extensive descriptions of a quasi-experimental approach to addressing the effectiveness of participatory ergonomics and the study is weak from and experimental design perspective.

A more quantitative study on a participatory ergonomic process of improving office work was reported by Vink and Kompier (1997). In the first stage of the project, the work stations of 12 people who entered salary data at high speeds in a large government office were studied before and after the introduction of adjustable chairs, tables and other "ergonomic" equipment. Based on "comfort" data of these twelve, "ergonomic" furniture and other accessories were ordered and 33 additional employees received instructions and training on their "ideal" work station. Five months later, deviation from the "ideal" work station layout was measured for both the group of 12 who participated in the initial experiment and the remaining 33 who received instruction and training only. There were significant improvements in comfort for back and neck complaints with the new work stations for almost all employees. Those who received only instruction deviated more from ergonomic recommendations in setting and layout of components of the work stations than the original group of twelve. Participation in the experiment part of the project, itself, seemed to intensify the effect on the twelve employees. The authors commented on the difficulty of conducting and controlling conditions of the experiment in the work place because of continual interruptions to the participants, sickness absence on evaluation days and other practical problems usually not encountered in the laboratory.

This is one of the better studies on the effects of participatory ergonomics but even this study is weak. There was no real control group and it is not clear just what the nature of the "participation" was. The group of 12 did not appear to be assisting in the decision making about either the type of furniture purchased or the ideal settings or layouts of the work station components. In effect, they seemed only to "participate" in more intensive measurements of their work stations and discomfort than the other employees.

One of the more extensively reported participatory interventions is not in ergonomics but in the area of occupational safety. It is a combined participatory and behaviour modification approach to attempt to reduce workplace accidents. The method could be applied to ergonomic interventions and for that reason we will briefly address the research. A study by Saari and Nasanen (1989), conducted in a ship yard, is a good example. They make no claim that they are the first to use this approach, citing Sulzer-Azaroff (1978) and others before them. However, this Finnish group seems to have used the method most extensively in a large number of industries.

The method focuses on occupational "housekeeping" in which a process is put in place to encourage workers to improve order and tidiness by keeping their work space uncluttered, replacing tools, making sure eye-wash fountains and fire extinguishers are accessible, etc. Small teams, the participatory part of the approach, comprising labour and management representatives are assembled to design a yes/no checklist of about 100 housekeeping items of relevance to their department. The team then administers the checklist on several occasions to obtain a base-line housekeeping level. The remaining members of the department are then assembled for about one hour of instruction on the importance of housekeeping for safety and are informed that their area will be monitored periodically. The results of successive audits using the checklist are displayed on a large graph in view of all workers, the behaviour modification part of the approach. This feedback is almost always positive, particularly at the beginning of the project because there are obvious things to improve easily. The scoring is simply the number of "yes" (tidy) ticks on the checklist as a percent of the total possible "yes" responses. Baselines are typically about 60% and rise over a period of six to eight weeks to 90%. These authors have shown the effect to persist for up to three years following withdrawal of the graphical feedback.

The interesting finding, according to the authors, is that although one might expect a reduction in accidents of about 25% from improved housekeeping, the number of accidents often reduces by 70-90%. The reasons for this dramatic improvement are speculative but plausible explanations are that people generalize the learned (safety) behaviour to other hazards and either remove those risks or are more careful in risky environments. In addition, Saari (1984) has suggested that when a workplace is tidy, there is more capacity for a worker to notice other hazards or that the positive results encourage workers to take on all sorts of problems.

Saari (1992), argues that interventions should use positive reinforcement, not penalties for failure; that monitoring visible outcomes of behaviour changes (is the waste in the waste basket) is more successful and less threatening than monitoring the behaviours themselves (who is not picking up the waste); and that this participatory approach is not only a useful vehicle for improving the safety culture in a company, but is also an effective vehicle for improving communication between labour and management on many thorny issues by starting on a neutral topic, housekeeping. They have used the method successfully in many industries. Whether it is useful for introducing effective ergonomic changes in a company remains to be seen.

Once again, none of these studies has employed true experimental designs. Some are qualitative, most are before/after quasi-experimental designs with no true control group. None is randomized; usually groups are targeted for intervention because they have high injury rates, absenteeism or some other feature that needs improvement.

Economic Analyses of Ergonomic Interventions

In spite of continual call for cost/benefit or even cost/effectiveness analyses of ergonomic interventions, relatively few reports can be found in the scientific literature although there are many case study reports in professional periodicals. Cost/benefit analyses typically weigh the economic costs against the economic benefits of an intervention. Cost/effectiveness analyses weigh the costs against a non-monetary benefit such as a reduction in the number of adverse movements of the upper limbs or torso, reductions in absenteeism or labour turnover rates attributable to an intervention.

Andersson (1992) points out that economic evaluations of ergonomic solutions can be effectively used in the formal accept/reject decision of a particular solution or in choosing among several, in ranking several project proposals or in controlling the costs of implemented interventions against budget. Several economic indicators can be calculated depending upon the type of input data available. They include the calculation of “net present value”, the present value equivalent of all cash inflows less all cash outlays associated with a project; the “internal rate of return”, i.e. the rate of interest that would equate the discounted present value of expected future receipts to the present value of the cash outlays for the intervention with an expectation that the interest rate would exceed some minimum expected for return on investment (e.g. 20%); the “payback period”, the time usually expressed in years to regain the cost of the intervention. Each of these economic ratios has its strengths and weakness and requires different assumptions and input data. There are excellent descriptions of these methods and discussions of their strengths and weakness is several articles aimed at non-economists (e.g. Oxenburgh, 1991; Andersson, (1992a,b); Riel and Imbeau, 1996, 1997).

The paper by Riel and Imbeau (1997) is important for the thorough description of processes, methods and an example in their economic analysis applied to ergonomic decision making. The example was in a plant that manufactures helicopters and required the manual handling of heavy dies. There were many overexertion and bodily reaction types of injuries. One of the important aspects of this study was their demonstration that their economic analysis could be applied to a single work station for the purpose of deciding whether to implement an intervention of a particular type or not. The intervention was the purchase of a hydraulic table and set of rollers to reduce the manual handling. A number of points of interest were developed in the paper. They include the notion that economic analyses make the implicit assumption that economic aspects of potential accidents are linked to a particular work station; that uncertainty as to type of accident that may ensue affects the cost projections (some injuries are more costly than others) and that uncertainty considerations are often missing from economic analyses; that when considering insurance costs, costs in the first year of a study are reflections of several previous years, not just the current year and that benefits of reduced insurance costs will persist several years beyond the investment at year one. Therefore, the horizon ought to span a time period that corresponds to the entire life of the intervention (equipment in this case) within reason. Their analysis showed that if only medium term effects were considered, the investment in the hydraulic table and rollers ($10,000) was not attractive but if a longer term horizon was considered, with all of its assumptions, the project desirability is likely to increase.

There are many health and safety magazine and conference proceeding descriptions of case studies on versions of economic analyses of ergonomic interventions. For example, Darcangelo (1989) reported that Northern Telecom in Calgary saved $95,000 in less than two years as a result of reductions in repetitive strain injuries on one line for a cost of intervention of $23,000. The intervention included an employee awareness program, injury treatment protocols, a work place assessment and recommendations for change. Lost time accidents dropped from 20 to 4. The savings were reported to result from a $29,600 increase in productivity and reductions of $54,600, $6,900 and $4,700 in the costs of injuries, fatigue and material handling, respectively. There was no explanation of how costs attributable to “fatigue” or the other factors were calculated or a description of what changes in the work place actually occurred. Most case studies, if not all, suffer from lack of appropriate control groups, sketchy descriptions of exactly what the intervention was and the case study literature probably has reporting bias of successful interventions, a problem also with the scientific literature. These problems notwithstanding, there are enough success stories on which to base testable hypotheses about the potential utility of ergonomic interventions of various types.

There are some interesting examples of economic analyses in the scientific literature. Aaras and Westgaard (1987), alluded to earlier, showed that work station redesign in a telephone exchange and cable assembly operation in Norway resulted in a reduction of the number of musculoskeletal sick leaves on one of the jobs from 25% of the female workers employed from 0 to 2 years on that job to zero for this group working on a new ergonomically designed work station. For those who had been working for more than five years the reduction was from 60% to 30% of the workers, possibly an effect of a group with WMSD that could now not be eliminated regardless of the quality of design of the new system. The mean duration of sick leave dropped from 72 to 47 days on the redesigned work station which they showed, via electromyography, to require lower muscular demand than the old system. Spilling, Eitrheim and Aaras (1986) used these data and showed a cost savings against cost of intervention of about $60,000/year (1986 Cdn dollars) for 12 years. The major saving was a dramatic reduction in employee turn-over rate that appreciably reduced recruiting and retraining costs. Over the prolonged duration of this study a number of economic changes occurred in the country and in the plant, the major problem with a before/after study design. However, interviews with workers indicated that they thought that perhaps 50% of the reduction in costs and improvements in retention of the work force could be attributed to the ergonomic intervention.

Narayan and Rudolph (1993) reported that ergonomic improvements in a medical device assembly plant that had high upper limb and some low back WMSD resulted in a dramatic reduction in incidence but, in particular, in severity on the jobs that had be redesigned. The jobs required very fine finger manipulation of materials and tools in prolonged awkward, static postures of the torso and wrists. Seating, lighting and workspace layout were generally poor. They used a participatory approach to the analysis of design problems, and workstation redesign, including mockups of prototype workstations, following a one day ergonomics awareness program for plant staff. Plant-wide reduction in lost-time from 155 to 68 days per 200,000 worker-hours over a one year period occurred although as the company started implementing design changes the reporting of injury increased. This resulted in lower than hoped for statistics on incidence but the duration of lost- time days decreased. The participatory process was successful in leaving the plant with the capability of assessing its operations on an ongoing basis. The economic analysis was simple although relatively informal. As an example, costs for one job (20 workers) included the research on the work stations, some redesign charges and the cost of new equipment such as chairs and footrests ($23,600). Benefits included compensation and lost time costs ($127,300). The payback period was 2.3 months.

Lanoie and Tavenas (1997) also implemented a participatory ergonomics program to attempt to reduce back-related disorders among packers at a warehouse who handle boxes full of liquor. A formal analysis of the costs and benefits of the intervention was described. A joint group of management and labour received five days of ergonomics training and subsequently met once a week to discuss safety problems and their solutions. Solutions included changes such as the purchase of a new "truck" seat, pallet movers and mechanized plastic wrapper. The outcome was that the program did not have a significant impact on the total number of accidents but it did reduce back-related injuries. In fact, the focus was on this type of injury but there was no spill-over effect of the participatory approach reported by Saari (1992). A strike interrupted the project and my have destroyed the improved communication between management and labour that participatory approaches have been reported to facilitate. The economic analysis showed that the "net present value" was slightly negative (-$8,000) but strongly positive ($188,000) if costs and benefits were projected over a five year period because of the amortization of the capital outlay. Although this study identified benefits of a participatory ergonomic intervention, its main value is the thorough description of the economic analysis that was done with considerable effort to include as many costs as possible and to discuss possible non tangible benefits in addition to those that could be measured.

Perhaps the most ambitious of the economic analyses of ergonomic interventions is that reported by Oxenburgh and Guldberg (1993). They attempted to estimate the costs and financial benefits to industry in an entire country, Australia, to comply with a "safe manual handling code of practice" prior to the introduction of legislation. The draft code contained many features intended to reduce the incidence, severity and costs of occupational injury. One of the proposed requirements was a load limit of 16 kg. Therefore, the authors attempted to determine the costs to companies of having to comply with a 16 kg load limit and the expected reductions in injuries and their costs if a 16 kg load limit was in place. They selected the sectors that collectively accounted for 80% of workplace manual handling injuries. These sectors also accounted for 56% of the Australian work force (manufacturing, construction, wholesale and retail trade, transportation, hospitals/nursing homes). Twelve interviewers conducted interviews with more than 200 managers of randomly sampled companies in these sectors. They sought information about work stations where manual handling occurred, accident statistics, tasks that caused injuries and the managers estimation of the costs of complying with a 16 kg load limit. These costs might include purchase of hand carts, fork lifts, conveyers, cranes, etc. Where possible the interviewers observed and assessed the relevant workstations to make their own judgements.

The authors reported that due to sample size the capital cost estimate was subject to an error of about 20%. On the benefit side, the draft code was estimated to reduce the total manual handling injuries by about 27%. Monetary benefits from this size of reduction were then estimated from known average costs of these injuries but no attempt was made to estimate any changes in productivity that might result from introduction of the code. The calculations showed that about 74% of the initial capital cost to comply was to reduce lifting in the heavier range of lifts - above 34 kg, with the greater share being borne by small manufacturing industry. While managers complained about having to comply with lifting limits below 16 kg, few argued that 34 kg was acceptable.

It was estimated that the code would save about $A 156 million per year against recurrent annual costs of about $A 245 million for a net cost of about $A 89 million. However, only the direct, not the indirect costs of injuries were included in the estimates. Indirect costs of absenteeism have been estimated by numerous authors to vary from about 1.5 to 10 times the direct costs. Furthermore, only the weight lifted was taken into account, not the injury problems encountered when light weights are handled in adverse trunk postures or injury related repetitive handling of lighter loads. The authors argue that since there was resistance in the country to a code based on loads less than 35 kg and since there was no clear evidence for effectiveness of such codes to prevent injury, the strategic thing to do would be to introduce a 35 kg limit initially and gradually move to a code with a lower load limit as acceptance of the original code accumulates. Unfortunately, cost estimates like these are extremely difficult to make and the consequences of gross errors of estimate can be substantial from the point of view of policy development and implementation.

Summary

There is accumulating, high quality laboratory and epidemiological evidence that shows, in the environments in which the studies were conducted at least, that a combination of physical demands of tasks and worker perceptions of their job and the work environment interact to elevate risk of reporting pain of work-related musculoskeletal disorders. Moreover, quite a lot is known about how to measure the risk factors but there is considerable debate over whether limit values to allowable exposure to the risk factors can or should be identified.

However, there is very little research on interventions that is sufficiently well designed and implemented to be unequivocal in its conclusions. There are good reasons for this state of affairs. This type of research is very difficult to do for many reasons that include: a work environment that changes more rapidly than the time it takes to complete a well designed study; the difficulty in finding, and the ethics and natural change in the work place that inhibits maintenance of proper control groups for the duration of a study; the high costs of studying sufficiently large groups to obtain acceptable statistical power to be confident that lack of observed differences between intervention and control groups are real; inducing companies to get involved in this type of research given inevitable interruptions and the risk of finding results perceived by management or labour to be adverse or costly.

There is considerable efficacy research at the level of biomechanical indicators carried out by researchers in laboratories or in workplaces that shows, usually under ideal conditions, reduced physical demands as a result of various interventions such as tool or job redesign. There is some, but much less, effectiveness research carried out under normal working conditions in plants and businesses by workplace personnel; there is a little, but very little, research on the costs and benefits of ergonomic intervention in the work place. There are many case studies at all of these levels that show benefits of interventions of various types, but with all the attendant limitations of case studies, well known to sceptical reviewers, including bias of reporting positive but not negative results. This is a problem in the scientific literature as well. Where interventions can be more easily applied to large numbers of people, typically training, personal protective equipment or administrative interventions, more robust evaluation is available. In fact a number of randomized trials are now available. These have permitted better evaluation of these intervention for organizationally important outcomes such as absenteeism, back injury incidence and back pain, (van Poppel et al 1997).

Development of musculoskeletal disorders appears to be a have multiple risk factors; would seem unlikely that a single “magic bullet” will prevent their development. This is even more true if work absence and return to work are the issues of concern.This would suggest that the organization has to be considered as a whole, with intervention at several levels simultaneously, before costs will decline.

Recent reviews of priorities in occupational health research in the UK (Harrington and Calvert, 1996), in the Netherlands (van der Beek et al., 1997) and the USA (Rosenstock, 1996) all concluded that musculoskeletal disorders were a major problem. The Netherlands and the USA have targeted the design, implementation and evaluation of interventions in WMSDs as being of great importance, particularly their cost/benefit analysis. We concur.

Issues and Future Directions

A number of issues must be addressed if high quality, high productivity and high profitability of products and services are to be achieved in Canada. The social and monetary costs of occupationally related injury and illness must be reduced. To do this, work must be designed so that it does not harm people. The question is, are these objectives compatible? Can production or service processes and practices, tools, equipment, materials, work space layout, work pace and duration all be designed to minimize heavy and/or repetitive and/or prolonged work and, at the same time, maximize productivity and profit? In an advanced business and industrial culture, we believe that the answer should be, unequivocally, yes.

The answers to these questions cannot be found on the shelves of libraries. There are speculations about the answers and there are partial answers but we believe that the following issues must be addressed before there will be appreciable change in the costs of occupational injury and illness.

1. Determining risk factors for WMSD has been mainly a researcher lead effort. It is not clear that the next phase of the effort, prevention of work related musculoskeletal disorders, can continue in

the same way because of the difficulty of outsiders intervening in the business of the workplace. However, in the experience of the authors, it is difficult to engage management in research studies (as opposed to service delivery) in their plants. Indeed, their understandable view is that they produce goods or services and they are not in the business of doing research. Without workplace involvement, advancing knowledge about what interventions work and which do not and why, cannot be done.

How can management and labour be motivated to get involved in intervention and other research studies in their companies (e.g. direct financial incentives of temporary reductions in WCB premiums)?

2. We suspect that many of the training programs designed and implemented by consultants and safety associations often fail to incorporate the best knowledge available. Most certainly they suffer from absence of rigorous evaluation of effectiveness in improving knowledge, changing behaviour and in reducing occupational illness and injury, the ultimate objective. We are also of the impression that much more attention is paid to safety issues than to work design ergonomic issues or occupational disease issues.

How can programs that are already implemented, some at considerable cost, be properly evaluated for achievement, not only of process objectives, but of outcome objectives (e.g. convincing data on cost savings)? Is it necessary to expand the education and foci of WCB/WSIB or government personnel charged with the responsibility of disseminating information to workplaces?

3. What minimal level of research or evidence rigor is necessary to convince various interested parties, such as management, labour, compensation boards, or legislators to change current practices? In a rapidly changing business environment it is not possible to wait for randomized control trials of evaluation of particular strategies. For example it has taken about a decade to reach the current (generally negative) evaluation of the effectiveness of “back belts”. This clearly cannot be taken as a model for other specific products.

4. At what interface(s) in the complex network of involved parties is intervention likely to be most effective for prevention of initial injury and for return to work?

There are many people in a large organization who are in a position to encourage ergonomic change aimed at reducing risk of injury, or to discourage change if they perceive that there is no problem or that change will slow productivity or adversely affect their current work practices. They include senior management (President/CEO, VP, Corporate HS&E), Plant and Area Management, Company Ergonomic or H&S Specialists, Front Line Supervisors, Floor Employees, Joint H&S Committee, Union and Ergonomic Committee people (See Figure 3).

Most of the people listed above are involved in the return to work directly, or indirectly. In addition, the network is expanded because plant nurses, primary contact medical practitioners (physicians, chiropractors), rehabilitation specialists, claims management people, the WCB (WSIB) claims policies, S&A insurance people, and provincial legislation all can have an effect (see Figure 4).

Will intervention at any **one** interface account for enough variance to show a difference in prevention of initial injuries or in return to work outcome measures, once a worker has been injured?

5. There are not enough well trained researchers with field experience in universities or ergonomics practitioners currently employed in Canadian industries to be able to meet a dramatically increased demand in designing and implementing ergonomic intervention research on a large scale, should a demand eventuate. The issues raised above are multidisciplinary and require active involvement of workplace personnel to be successful. There is no established mechanism for bringing the multidisciplinary research teams together with workplace people, no culture of participation by companies in this type of work, incentives to them to become involved in this type of research (see #1), or sufficient research money available to conduct the work in most parts of Canada. Quebec may be an exception and new or expanded occupational H&S research initiatives in B.C, Ontario and Manitoba may help to address this issue. How can resouces necessary to make a difference be acquired and how can efforts in different parts of the country be coordinated or at least linked for information exchange purposes?

6. Are injury absence costs most effectively reduced by building safety interventions (e.g. ergonomic job modification) into company quality and productivity operations rather than into safety or human resources operations? Currently most H&S involvement rests with Human Resources departments rather than in the production end of the operations. They are sometimes seen by production people to be a necessary annoyance rather than people who should be able to increase profit margins and possibly quality and productivity by reducing injury absence. The administrative location of people leading intervention in a company may have an effect on the success of outcome.

7. How much money can a company expect to save through intervention and what is the evidence? This issue points to the need to include cost and benefit considerations in as many intervention studies as possible. It is recognized that intermediate outcome measures in all studies are essential but it is unrealistic to avoid dealing with monetary aspects of health and safety. This issue also points to the need for management, business and economic expertise on most intervention research teams and the need for management cooperation in revealing financial information and assisting in selecting relevant outcome indicators of costs, profits, productivity and quality and interpretation of data.

8. How can " best current practice" be created and disseminated among organizations?. Is information obtained from intervention research at large companies relevant and transferable to small businesses? If not, how does one communicate with the thousands of small businesses and get them involved in intervention research? How is information effectively communicated to small business?

9. Despite a sophisticated international research expertise in the evaluation of exposure and priorization of risk for jobs, companies do not yet have available tools of established reliability and usefulness for addressing risk factors for musculoskeletal disorders such as are found in occupational hygiene. Development and application of a range of methods, from checklist to instrumented measures is need to help organizations identify hazards, implement controls and manage their own workplaces.

10. Although many risk factors for low back pain and upper limb disorders are known, the best known have to do with excessive peak forces. Relatively little is known about the effects of time on predisposing soft tissue to damage, particularly the effects of low level but prolonged or repetitive loading in the workplace. Considerably more research is needed in this area, especially if limits to exposure are to be understood.

11. The majority of efforts over the last two decades have been devoted to determining the work-relatedness of musculosketal disorders. In these authors opinion, the conclusion to be drawn is that there is moderate to strong evidence that many musculoskeletal disorders have a substantial work-related component, This is not to imply that thresholds and dose-response relationships of risk factors are clear. They need continued research. However, it is necessary to add to the research agenda, good studies on the development, implementation and evaluation of the effectiveness of various approaches to interventions to reduce risk of injury, social and monetary costs. There is some research evidence and many case studies that suggest that ergonomic interventions reduce risk and cost of occupational injury but the study designs have generally been weak. Furthermore we suggest that the specific research question(s), the experimental design, the plan for data acquisition, interpretation and dissemination must be planned with the potential user groups if utilization of results, even at a local level, is to be realized.

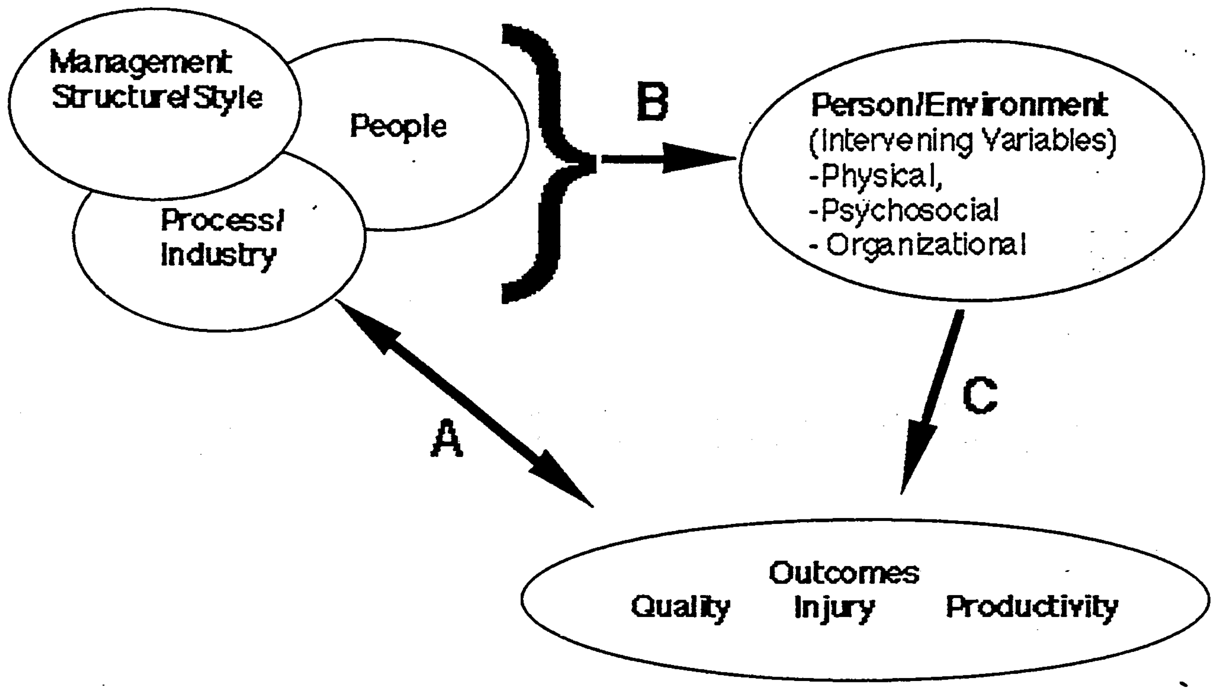

Figure 3 Model of the workplace and outcomes of interest in ergonomic interventions. Study of risk factors and interventions can proceed at a macroscopic level, e.g. job title, mandatory policy on wearing of back belts, etc. This is shown by Path **A**. The question is where in this cycle is the most effective place to intervene, or is it necessary to intervene at all or most entry points in the cycle given that only a small positive impact can be expected at any one point? Unfortunately, any single entry point can block change. We suggest that the study of interventions follow the intervening variables which have been shown previously to be risk factors, Paths B and C. This allows better description of *how* the intervention changed the workplace or *why* it did not have an effect on musculoskeletal disorders.

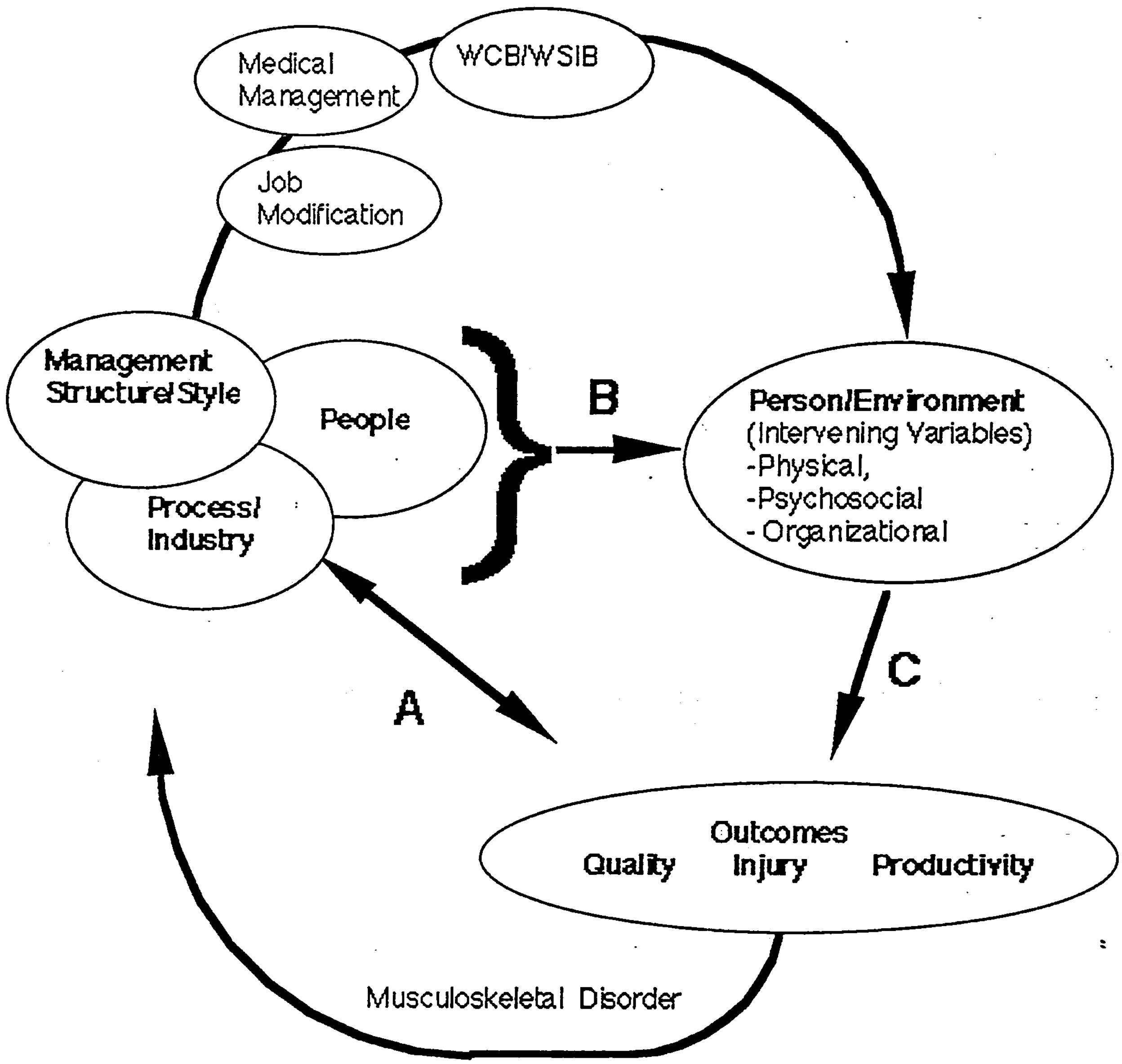

Figure 4 Model of the workplace and outcomes of interest in study of secondary prevention. This model is the same as that in Figure 3 except now, many new players can be involved, complicating the the process of return to work.

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