A Randomised and Controlled Trial of Participative Ergonomics for Manual Tasks (PErforM)

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Abstract

A participative ergonomics approach to reducing injuries associated with manual tasks is widely promoted, however only limited evidence from uncontrolled trials was available to support the efficacy of such an approach. This paper reports on a randomised and controlled trial of PErforM, a participative ergonomics intervention designed to reduce the risks of injury associated with manual tasks. One hundred and seventeen small to medium sized food, construction, and health workplaces in South-East Queensland were audited by government inspectors using a manual tasks risk assessment tool (ManTRA). Forty-eight volunteer workplaces were then randomly assigned to Experimental and Control groups with the Experimental group receiving the PErforM program. Inspectors audited the workplaces again, nine months following the intervention. A significant decrease in estimates of manual task risk was observed in the intervention group, as was an increase in risk assessment activity and improved management systems for manual task risk assessment and control. These data provide strong evidence for the efficacy of participative ergonomics approaches to reducing the risk of musculoskeletal injury associated with manual tasks.

Introduction

Musculoskeletal injuries related to the performance of manual tasks have been recognised as a source of significant pain, disability and disadvantage for the injured person and a substantial burden on modern societies. Statistics across a range of jurisdictions suggest that more than 30% of all occupational injuries are musculoskeletal injuries associated with manual tasks (eg., NOHSC 1998, Liberty Mutual 2002).

One approach to reducing the burden from musculoskeletal injuries is participative ergonomics. Participative ergonomics developed from quality circles in Japan (Noro 1991), industrial democracy and social participation in Europe and Scandinavia (Jensen 1997), and the failure of traditional corporate control models to bring economic growth to USA companies in the 1970s (Brown 1993). Whilst there are many variations in the models and techniques used in participative ergonomics (see Haines and Wilson 1998 for a review), the basic concept is to involve workers in improving their workplaces to reduce injury and increase productivity. In this way the expert knowledge workers have of their own tasks is utilised to assist in risk assessment and control.

Potential benefits of participative ergonomics are thought to include an improved flow of useful information within an organization, an improvement in the meaningfulness of work, more rapid technological and organisational change, enhanced performance and reductions in work related health problems (Brown 1993, Haims and Carayon 1998). Participative ergonomics has been used to create more human centred work (Imada 2000), to improve work organisational climate (Maciel 1998), to reduce mental workload (Vink et al. 1995) and to rehabilitate workers with back pain (Loisel et al. 2001).

Participative ergonomics has also been used to try to prevent musculoskeletal disorders associated with manual tasks across a range of industries including electrical manufacturing (St-Vincent et al. 1998), car manufacturing (Halpern and Dawson 1997), meat processing (Moore & Garg 1997, NIOSH 1994), print media (Rosecrance and Cook 2000), office computer work (Westlander 1995), construction (de Jong and Vink 2000, Vink et al. 1997) and health (Straker 1990); and it is now the internationally recommended approach to reducing musculoskeletal diorders associated with manual tasks (Carrivick et al. 2001, DOL 1999, Jensen 1997, NIOSH 1997, Stubbs 2000). Despite this, there is only limited evidence to support the efficacy of such an approach.

Evidence for the Efficacy of Participatory Ergonomics

Many uncontrolled case studies of participative ergonomics have been reported, with some showing improvements in health outcomes. For example, Koda et al. (1997) reported an increase in risk control actions and a decrease in compensable back pain incidence in an uncontrolled trial in the Tokyo waste disposal organization. Conversely some case studies have found a deterioration in health outcomes following a participative ergonomics intervention. For example, Moore and Garg (1997) reported an increase in musculoskeletal disorder incidence rate and lost time incidence rate in an uncontrolled trial in a meat processing plant. (Their latter paper [1998] reported a marked decrease in lost time incidence rate.) However the absence of a comparison group means that the cause of any changes found in these and similar studies may not have been due to the intervention alone.

Wickstrom et al. (1993) conducted a more strongly designed study in the metal fabrication industry in Finland. A participative ergonomics intervention was delivered in one factory, with a similar factory acting as a comparison. This eliminated some confounding factors, such as the impact of general economic conditions over time. A decrease in back pain in the intervention factory was reported, while no change was observed in the comparison factory.

A study with even better control was reported recently by Carrivick et al. (2001, 2002). This study involved an intervention for cleaners in one hospital in Australia and compared outcomes with orderlies in the same hospital, cleaners in a nearby comparable hospital, and cleaners in the whole of Western Australia. The intervention group experienced substantial reductions in injury rate, injury duration and injury costs, compared to increases in the comparison groups.

The Wickstrom et al. and Carrivick et al. studies provide reasonable levels of evidence for the efficacy of participative ergonomics to improve musculoskeletal injury outcomes. However, as the intervention and comparison groups were not randomly assigned, confounding factors may have caused observed differences. This limitation in the available evidence has impeded the implementation of participative ergonomics at an organisational level and at a government level (eg the difficulties associated with the introduction of an “ergonomics standard” in the USA). Randomised and controlled trials are recognised as the highest level of evidence (Sackett et al. 1997). Whilst the need for randomised and controlled trials in ergonomics has been recognised (Straker et al. 2001), only two such trials of participative ergonomics interventions have been reported.

Morkden et al. (2002) recently reported on a randomised and controlled trial in the Norwegian aluminium industry evaluating worker versus supervisor and manager training forms of participative ergonomics. Employees from eight plants were involved with supervisors and managers only, whole work teams, or work teams without their supervisors, in two departments assigned to participative ergonomics training or no training. Within the intervention groups, some groups had the supervisor only trained whilst others had the whole work team trained. Control work teams were on different shifts but were aware of the study and were consulted about control changes. Other departments in the plants formed a secondary non-randomised control group. The authors reported an increase in coping strategies in the intervention group but no changes in job control or musculoskeletal symptoms.

Earlier, Loisel et al. (1997) reported on a randomised and controlled trial using participative ergonomics to return people with back pain to their work. They found that the use of a group (including ergonomist, injured worker, supervisor and management and union representatives) to evaluate and generate solutions to hazards in the injured worker's worksite resulted in a more rapid return to full work duties than medical management.

No randomised and controlled trial of any ergonomics approach to reduce injuries at a workplace level has previously been reported. This is at least partly due to the resource and logistic difficulties in mounting a randomised and controlled trial involving multiple organisations (Straker 2000a).

Measures of Participative Ergonomics Efficacy

Studies attempting to evaluate the efficacy of participative ergonomics interventions to reduce musculoskeletal disorders have used a plethora of outcome measures ranging from ratings of efficacy by a participative ergonomics committee (Rosecrance and Cook 2000), through physical measures such as heart rate (Pohjonen et al. 1998), to productivity measures (Maciel 1998) and cost-benefit analysis (Lanoie and Tavenas 1996).

Straker (2000b) classified the possible measures as either short or long term. Short term measures included measures of procedural activity, physical risk measures and psychosocial measures. Long term measures included productivity and health outcomes.

Procedural measures could include direct risk assessment and control activities as well as more indirect activities such as the development of appropriate management systems and policies. Physical risk measures could include observational ratings, physical measurement of hazards (eg. weight of box), measurement of biological responses (eg. heat rate) and estimates of biological stresses (eg. low back moment). Psychosocial measures could include ratings by individuals of their discomfort, exertion, workload and satisfaction and estimates of the organisational environment such as safety culture and team cohesion.

Productivity measures could include work unit output, product quality/failure rate, system down time, absenteeism. Efficacy has also been evaluated using cost-benefit analysis. Long term health outcomes commonly used include musculoskeletal injury incidence rates, durations and associated costs.

The limitations of the various measures have been discussed previously (see Burdorf 1992, Straker 1991 and 2000b, Li and Buckle 1999a and b) and it is clear that no single measure is adequate.

Aim

The aim of the current research was to evaluate the efficacy of a participative ergonomics intervention aimed at reducing injuries associated with manual tasks through a randomised and controlled trial using a battery of outcome measures. This paper describes the physical risk estimates, legislative compliance, procedural activity, and organisational environment outcome measures obtained for randomly allocated Experimental and Control workplaces. The project also evaluated productivity and workers' compensation outcomes and used in depth interviews to investigate the process of implementing a participative approach, and these data will be reported elsewhere.

Method

Design
A randomised and controlled trial was conducted to evaluate the efficacy, in terms of a range of outcome measures, of a participative ergonomics intervention aimed at reducing injuries associated with manual tasks in small to medium sized workplaces in three diverse industry sectors. An initial manual task audit of 117 randomly selected workplaces was undertaken by government inspectors between October and December 2000. These workplaces were invited to participate in the evaluation of the intervention, and 48 workplaces volunteered. Thirty-one of these workplaces were randomly assigned to the Experimental group and the remainder formed a Control group. Workplaces in the Experimental group received the intervention between March and July 2001. All workplaces, and an additional 30 similar workplaces which were not audited initially, were again audited between April and July 2002. The intervention was made available to Control workplaces in August to December 2002. This paper reports data obtained from the volunteer workplaces only (Experimental and Control).

Sample
Queensland is a large state in the North-East of Australia, covering 1.7 million km^2, with a population of 3.5 million people. The South-East corner of the state is relatively densely populated, with 65% of the population (2.3 million people) in an area equal to 1.3% of the state (22,339 km^2).

Workplace health and safety legislation in Australia is largely a State government responsibility, and the relevant authority in Queensland is the Division of Workplace Health and Safety in the Department of Industrial Relations. This authority maintains a database of all workplaces in the State, and inspectors employed by the authority have right of entry to inspect any workplace, without notice, to assess compliance with the Workplace Health and Safety Act (DIR 2000). Under the Act, workplaces employing 30 or more staff are required to manage the risk associated with manual tasks, have a Workplace Health and Safety Officer and must establish a health and safety committee. To assist employers to meet their obligations under the Act, the Department provides advisory standards, including a Manual Tasks Advisory Standard enacted in February 2000 (DWHS 2000). The Advisory Standard also advocates a consultative, participatory approach to risk assessment and control as the main approach to reducing associated musculoskeletal injuries.

The workplaces chosen for the initial audit employed 30-100 employees, were single workplace employers (ie, not part of a larger organisation), located within South-East Queensland, and in one of three industry sectors. Small to medium sized workplaces were chosen as these have been identified as an area of need because they employ a large proportion of the workforce yet have limited ability to provide in house ergonomics expertise. Independent organizations were required so the workplace management could make decisions not constrained by remote, higher level management.

The industry sectors were chosen in consultation with Division of Workplace Health and Safety staff after a review of relevant compensation statistics. The workplaces chosen for initial audit conducted business in: food processing other than meat (Australia and New Zealand Standard Industry Classification [ANZSIC] codes 2112-2190); construction related manufacturing and wholesaling (ANZSIC 2323, 2741, 2742, 4531, and 4539); or health and community services, specifically nursing homes and accommodation for the aged (ANZSIC 8613 and 8721). For the sake of brevity, the industry sectors are hereafter referred to as "Food", "Construction" and "Health".

Procedure

Following identification of all workplaces which met the inclusion criteria (N=162), 120 workplaces were randomly selected for initial audit. Three workplaces were not able to be audited due to closure or some other reason. Seventeen government Workplace Health and Safety inspectors were trained by the investigators in the use of a Manual Tasks Risk Assessment tool (ManTRA) which incorporates assessment of manual task risk levels, manual tasks related safety activity and organisational environment (further details are provided in the following section). The Queensland government publicised that their inspectors would be conducting a 'blitz' on manual tasks, following the release of a revised Manual Tasks Advisory Standard in February 2000 (DWHS 2000). As required by the Workplace Health and Safety Act, where inspectors observed instances of tasks, which in the opinion of the inspector posed a significant risk of injury, the inspector was required to take action. This enforcement action involved either: a) issuing a prohibition notice which mandates immediate cessation of performance of the task; b) issuing an improvement notice which requires the employer to comply with the details of the notice within a given timeframe; or c) providing formal written advice regarding the nature of the risk.

Following the initial audit, all audited workplaces (N=117) were offered the opportunity to participate in the evaluation of a participative ergonomics intervention aimed at reducing injury risks associated with manual tasks. Due to project timing constraints, random allocation of volunteers was initially weighted towards the Experimental group. The expected number of volunteer workplaces did not eventuate and consequently the Control group was smaller than planned. Forty-eight workplaces volunteered and 31 of these workplaces were randomly assigned to the Experimental group. The remaining 17 workplaces formed the Control group. Workplaces allocated to the Control group were informed that, due to the design of the evaluation, their participation would be delayed until the following year. Table 1 provides a summary of the breakdown of workplaces by industry sector.

Table 1: Summary of workplace numbers by Group and Industry sector.

	Food	Construction	Health	Total
Experimental	8	7	16	31
Control	3	5	9	17
Refused	21	31	17	69
Total	32	43	42	117

Three ergonomists were trained in the delivery of a participatory ergonomics for manual tasks (PErforM) intervention designed by the investigators. The intervention aimed to improve each workplace's management systems to support participation in a risk assessment and control process; and provide supervisors and work teams with sufficient knowledge and skills to enable them to perform manual task risk assessment and control. The intervention was delivered to each workplace over a series of four sessions. In most cases these sessions were held on separate days, however some flexibility existed to accommodate individual workplace circumstances. An outline of the PErforM program is provided in Appendix A.

The intervention was delivered by the three consultants to each of the 31 workplaces over a six month period, although the involvement of each workplace typically spanned a period of less than three months. Workplaces were typically visited over several weeks to provide ongoing encouragement and support.

The investigators retrained five of the original inspectors and trained a further six inspectors in the use of ManTRA, and the second audits occurred between April to July 2002 (at least nine months after the delivery of the intervention was complete). The government again publicised the conduct of a manual tasks "blitz" in the mass media. The inspectors were not informed of which workplaces had volunteered for the intervention, or which had received the intervention.

Audit Tool

The audit tool used by the inspectors (ManTRA) was designed by the investigators to serve a dual purpose: (a) to assist inspectors to form an opinion regarding the compliance of the workplace with the requirements of the relevant advisory standard (DWHS 2000), and consequently whether any formal action was required; and (b) to provide the investigators with a method of assessing the level of manual task related safety activity, relevant organisational environment variables, and an assessment of the level and nature of manual task related injury risk present in the workplace. The usability, reliability and validity of the tool was tested with government inspectors and found to be good. A copy of the complete tool, and accompanying explanatory notes, is available from the UQ Ergonomics website (ergonomics.uq.edu.au/download/mantra.pdf – password available from robin@hms.uq.edu.au).

The initial sections of the audit tool involved identifying the jobs performed by staff at the workplace and the number of staff in each category. The inspectors then selected staff to interview with the intention of selecting a 10% representative sample of non-administrative or managerial staff. The number of staff actually selected for interview varied from 1 to 13 depending on the size of the workplace and the inspectors' perceptions of the degree of risk present at the workplace. At least one supervisor, and at least one person with responsibility for purchasing, were also interviewed using questions provided in the audit tool.

The questions asked of employees included a measure of procedural activity based on Cheyne, Cox, Oliver and Tomas' (1998) Safety Activity measure. Employees were asked to indicate whether they had participated in certain safety activities in the past twelve months. Cheyne et al.'s list of activities was modified to reflect the focus on manual tasks (eg, Cheyne et al.'s "Seen a safety video" was re-written as "Seen a manual task safety video"). Activities not related to manual tasks were omitted (eg "took place in fire evacuation practice"). The final list consisted of nine activities. Managers were also asked about the number of manual tasks risk assessments carried out at the workplace, and the number of controls implemented.

The quality of the safety management system for manual tasks was indicated by the extent to which the organisation followed the guidelines for management of safety provided by the Division of Health and Safety (DWHS 1999). The Division's guidelines require management of:

- Health and safety policy
- Allocation of responsibilities and accountabilities for health and safety

- Sub-contractor and purchasing controls
- Health and Safety consultation with employees
- Risk management
- Provision of information
- Training
- Incident and injury investigation, reporting and recording

Supervisors, purchasing officers, and the employees who were doing tasks being analysed by the inspectors were asked questions targeting each of the elements of the management system relevant to their level. For example, supervisors were asked to indicate the extent to which their allocation of health and safety responsibilities was clear, specific, in writing and known to other employees (relating to the guideline on “allocation of responsibilities for health and safety”). Purchasing officers were asked if risk assessments were conducted prior to purchasing new equipment (guideline on “sub-contractor and purchasing control”). Employees were asked if they had received information on the health and safety policy and if so the source of the information (guideline on “health and safety policy”).

A confirmatory factor analysis of the data subsequently confirmed that the different questions designed to gain information on each guideline related to each other in the expected way. Information on the following factors was derived from the audits.

Factors from supervisors:
- Allocation of responsibilities for general health and safety
- Allocation of responsibilities specifically for manual tasks
- Training (for health and safety and risk assessment responsibilities)

Factors from purchasing officers:
- Sub-contractor controls
- Purchasing controls

Factors from employees:
- Communication of health and safety policy via line management
- Communication of health and safety policy via health and safety official
- Health and safety consultation representation
- Manual task risk management
- Training for manual tasks
- Incident and injury investigation

Further information on the organisational environment was also collected in a parallel qualitative study involving interviews with participating workplaces and ergonomics consultants. The results of the qualitative study will be reported separately.

The audit process also involved the inspectors asking employees questions about body discomfort, the tasks undertaken, and their opinions regarding the links between particular tasks and discomfort. On the basis of this information, the inspectors’ observations, and knowledge of the relevant industry, the inspector selected tasks for observation and coding for risk exposure using a matrix developed for this purpose by the investigators. The inspectors were requested to select a sample of two-three tasks for every worker and a sample of one worker for every 10 workers at a workplace, however the number of tasks chosen for examination was influenced by the inspectors' perceptions of the risk associated with tasks performed in each workplace.

The manual tasks risk matrix (see Appendix B) involves a rating of severity (on a five point scale) of risk factors for each of five body regions. For each task inspectors rated five body regions (lower limb, back, neck, shoulder/arms, wrist/hand) independently for seven types of risk. The types of risk were the total task time, duration of continuous performance without a break, cycle time, force, speed, awkwardness and vibration. Cycle time and duration of continuous performance scores were combined into a "repetition" risk factor (on a five point scale) using the table presented in Appendix B. Force and speed scores were similarly combined in an "exertion" risk factor. In this way the risk matrix was aligned with the direct risk factors for manual tasks identified in the advisory standard relevant to the jurisdiction (DWHS 2000).

For each task which was assessed, inspectors also made a decision about whether the task complied with legislative requirements or whether formal action was justified. If an inspector believed there was non compliance the inspector could: a) issue a notice prohibiting the task from being performed until changes were made; b) issue a notice requiring a workplace to improve the task in some way within a specified time-frame; or c) issue formal advice regarding a manual task risk. Issued notices placed a legal obligation on the obligation holder (eg. employee, employer, supplier), with the threat of prosecution and significant fines for lack of compliance.

Whilst the inspectors' decisions regarding whether to take action were based on the inspectors' opinions, guidance was provided to the inspectors that action may be indicated on the basis of the completed risk matrix when one or more of the following criteria were met: a) an exertion score of five for any body region; b) the sum of exertion and awkwardness was eight or greater for any body region; or c) the cumulative risk score (sum of total time, exertion, awkwardness, vibration and repetition) for any body region was 15 or greater.

Analysis

Four groups of dependent variables are reported in this paper: manual task risk estimates, inspector actions, procedural activity and organisational environment. Manual task risk estimates included:

- total assessed risk exposure (TARE) – the sum of cumulative risk scores for all tasks assessed at a workplace
- number of tasks assessed at each workplace
- workplace mean cumulative risk (total task risk across all body regions)
- workplace mean level of exposure to each risk factor (summed across body regions)
- workplace mean level of risk for each body region (summed across risk factors)
- workplace mean number of tasks which exceeded one or more action criteria

Inspector actions measures included the number of enforcement actions taken by an inspector at each workplace.

Procedural activity measures included:

- number of safety activities reported by employees
- number of manual tasks risk assessments undertaken, as reported by managers

- number of manual task risk controls implemented, as reported by managers

Organisational environment measures included information from supervisors, purchasing officers and employees based on the factor analysis as described above.

The independent variables for statistical analysis were group (Experimental, Control), Industry (Food, Construction, Health) and Time (Audit 1 pre intervention, Audit 2 post intervention). Three-way mixed model ANOVAs (Time as a repeated measure) were computed for the variables defined above using SPSS v10. Partial eta^2 was calculated as a measure of effect size (by convention, a partial eta^2 of 0.02 indicates a small, 0.15 a medium, and 0.35 a large effect).

Results

Total Assessed Risk Exposure

Figure 1 illustrates the workplace Total Assessed Risk Exposure for the Experimental and Control groups before and after the intervention for each industry sector and combined industries. Whilst the Experimental group appeared to start with a higher risk exposure, following intervention there was a clear trend for the Experimental group workplace risk exposure to reduce while the Control group risk exposure tended to increase or remain stable. A Time x Group x Industry mixed model ANOVA confirmed the Time x Group interaction ($F_{1,31}$ = 5.40, p = .027, partial eta^2 = .148). There were no significant main effects of Time ($F_{1,31}$ = 2.12, p = .155, partial eta^2 = .064), Group ($F_{1,31}$ = 1.07, p = .309, partial eta^2 = .033) or Industry ($F_{2,31}$ = 0.38, p = .690, partial eta^2 = .024) nor were the remaining 2 and 3 way interactions significant (Group x Industry $F_{2,31}$ = 0.49, p = .618, partial eta^2 = .031, Time x Industry $F_{2,31}$ =1.08, p =.352, partial eta^2 = .065, Time x Group x Industry $F_{2,31}$ = 0.20, p = .822, partial eta^2 = .013).

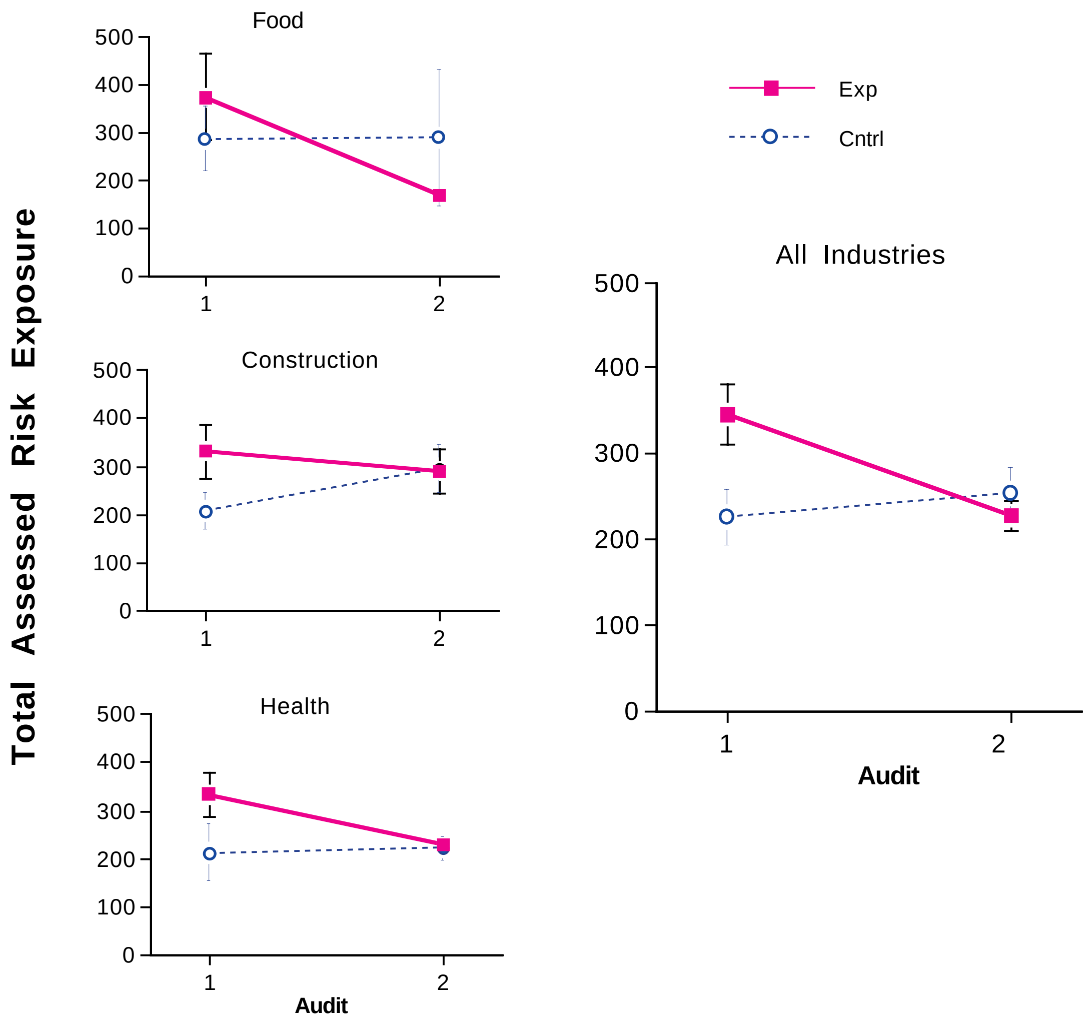

Figure 1: Workplace mean (±SEM) Total Assessed Risk Exposure by Group, Time and Industry.

Number of Tasks Assessed
Figure 2A presents the average number of tasks assessed at each workplace. A clear trend is evident with the Experimental group showing a decrease with the Control groups showing a slight increase. A Time x Industry x Group mixed model ANOVA approached significance for the Time by Group interaction ($F_{1,31}$ = 3.74, p=.062, partial eta^2 = .108). No main or other interaction effects were significant (eta^2.002 to .053).

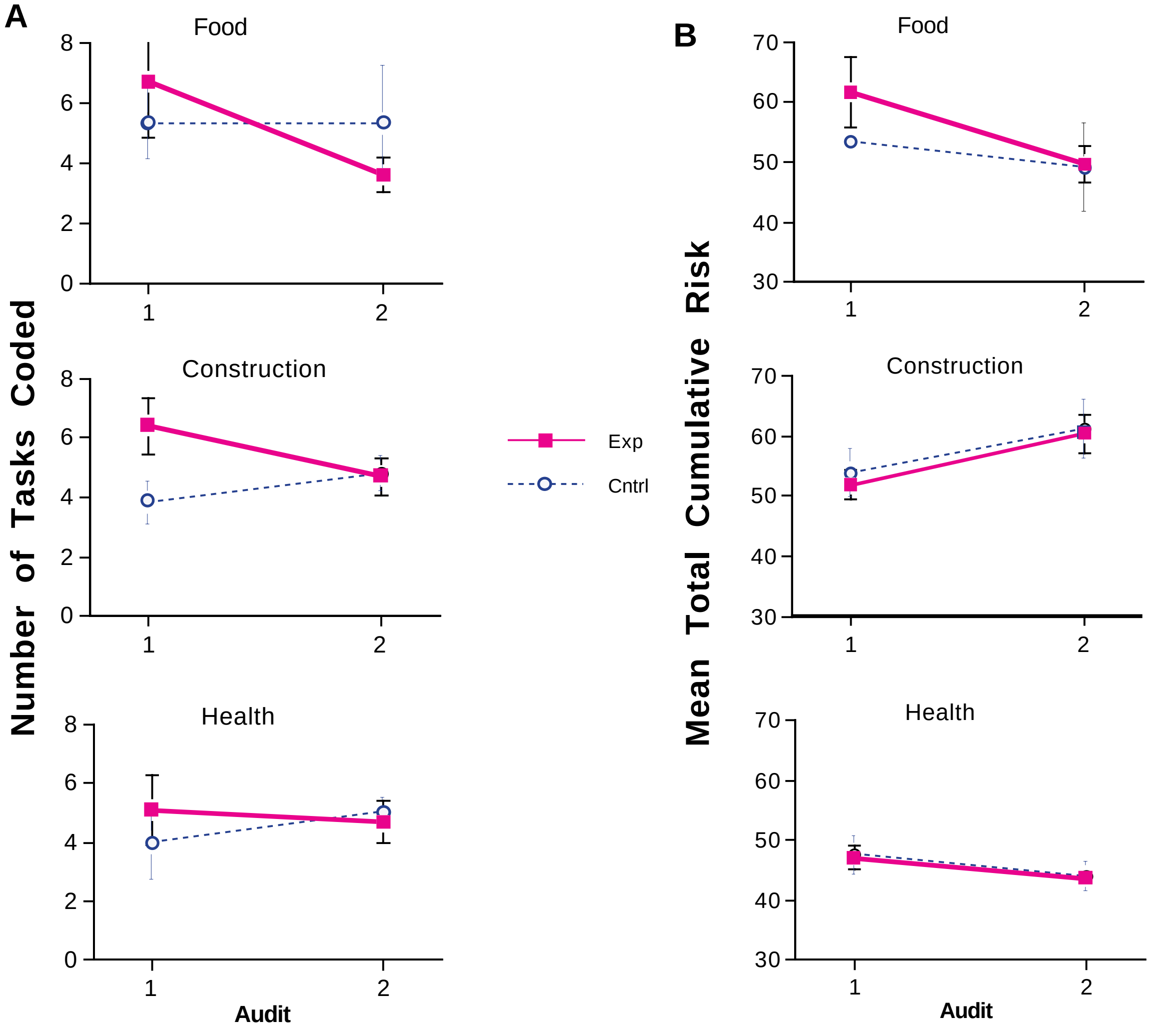

Figure 2: (A) Workplace mean (+ SEM) number of tasks assessed by Group, Time and Industry; (B) Workplace mean (+ SEM) total cumulative risk by Group, Time and Industry.

Total Cumulative Risk Score
Figure 2B illustrates the change in total cumulative risk estimates (workplace average sum of cumulative risk scores across all body regions) and suggests a decrease in Food Experimental group compared to Food Control group, and an increase for both Construction groups. Both Health groups started low and showed a small decrease over time. A Time x Industry x Group mixed model ANOVA for total cumulative risk found a significant main effect of Industry ($F_{2,31}$ = 8.98, p = .001, partial eta^2 = .220) and a Time x Industry interaction ($F_{2,31}$ =4.37, p =.021, partial eta^2 = .357). Health was significantly lower than both Food and Construction. There was no significant Time x Group interaction ($F_{1,31}$ = 0.13, p = .722, partial eta^2 = .004). There were no significant main effects of Time ($F_{1,31}$ = 0.10, p = .751, partial eta^2 = .003) or Group ($F_{1,31}$ = 0.39, p = .538, partial eta^2 = .012) nor were the remaining 2 and 3 way interactions significant

(Group x Industry $F_{2,31}$ = 0.51, p = .608, partial eta^2 = .032, Time x Group x Industry $F_{2,31}$ = 0.30, p = .745, partial eta^2 = .019).

Type of Task Risk

Separate Time x Group x Industry mixed model ANOVAs found no significant Time by Group interactions for any risk factor summed across body parts. There was a significant main effect of Time for task time, task duration, task force and task exertion and a significant Industry main effect for task time, task duration, task cycle time, task repetition, task awkwardness and task vibration. Examination of the changes in estimates of different types of task risk found a complex variety of responses, some of which are illustrated in Figure 3.

For example, task duration risk appeared to decrease in the Experimental Food group and increase in the Experimental Construction group (Figure 3A). Cycle time risk appeared to have a small decrease for the Experimental Food group compared with a small increase for the Control Food group, a larger decrease for Experimental Construction than Control Construction and a larger increase for Experimental Health than Control Health**.** Task force risk appeared to have a larger decrease in Control Food and Health groups than comparable Experimental groups (Figure 3B). Overall the trend was for more change in the time based risks and awkwardness risk for the Experimental groups than for the Control groups, with more change in the exertion risks for the Control group.

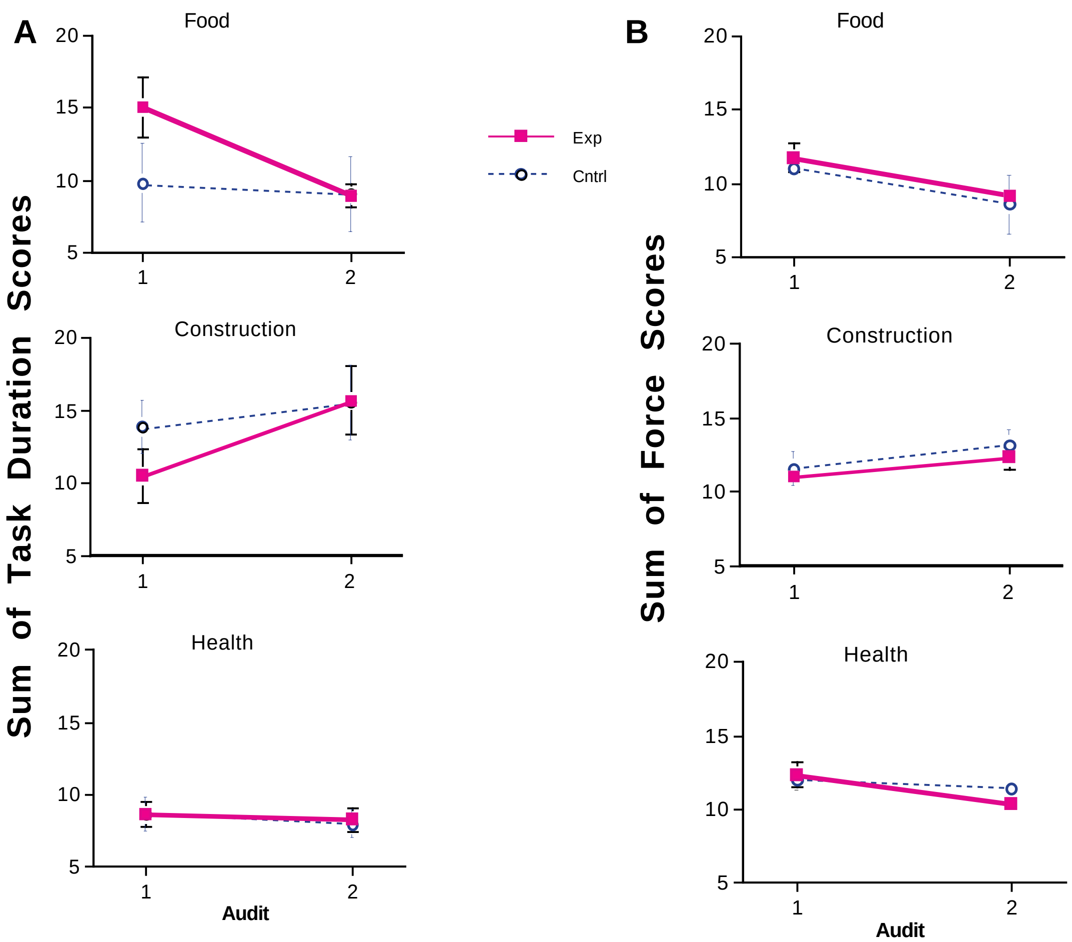

Figure 3: A) Workplace mean (+ SEM) task duration scores (summed across body parts) and B) Workplace mean (+ SEM) force scores (summed across body parts) by Group, Time and Industry.

Body Part Task Risk

In contrast to the variation in responses for types of task risks, the changes in risks for various body parts were more consistent. The Experimental Food group risks appeared to decrease across all body parts whereas the Control Food group risks remained the same or increased in neck and lower limb parts. The Experimental and Control Construction groups appeared to have an increase in risk in all body parts. The Experimental Health group appeared to have a decrease in risk in neck, back and lower limbs whilst the Control Health group appeared to have a decrease in all body parts (see for example Figure 4)

Separate Time x Group x Industry mixed model ANOVAs found a significant main effect for Industry in the wrist and hand, back and lower limb; a significant main effect for Group in the shoulder and arm, and neck, and a Time x Industry interaction for wrist and hand, shoulder and arm, neck, and back.

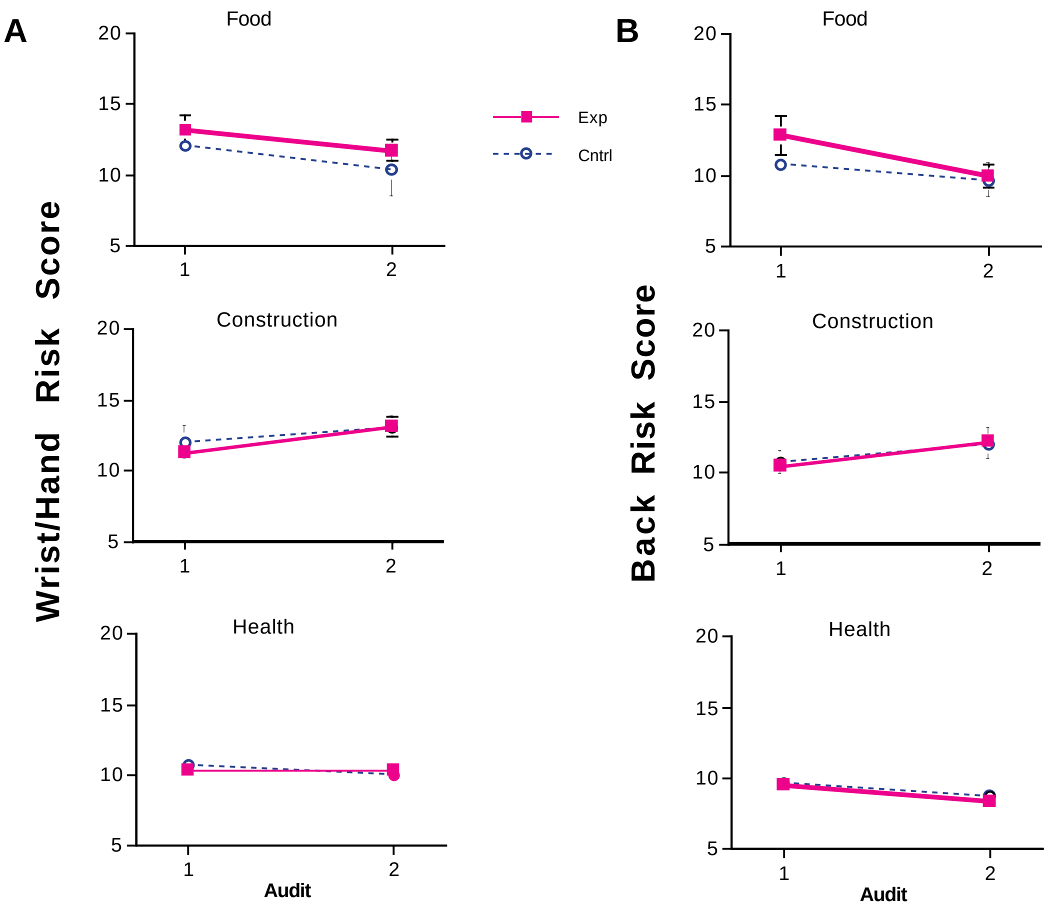

Figure 4: A) Workplace mean (+ SEM) wrist/hand risk (summed across types of risk factor) and B) Workplace mean (+ SEM) back risk (summed across types of risk factor) by Group, Industry and Time.

Task Risk Thresholds

The audit tool suggested to inspectors that action should be considered when, for any body part, the exertion score was 5, the sum of exertion and awkwardness was 8 or more, or the total cumulative score was 15 or more. Figure 5 illustrates the number of tasks assessed at each workplace which exceeded one or more of these criteria. A decrease in the number of tasks exceeding the action criteria was evident for Experimental workplaces in each industry, but not Control workplaces in Construction and Health industries. A Time x Group x Industry mixed model ANOVA found no significant effects although Time ($F_{1,31}$ = 3.88, p = .056, partial eta^2 = .093), Industry ($F_{2,31}$ = 1.72, p = .193, partial eta^2 = .083), Time x Industry ($F_{2,31}$ = 2.20, p = .125, partial eta^2 = .104) and Time x Group ($F_{1,31}$ = 1.50, p = .228, partial eta^2 = .038) showed small to medium effect sizes.

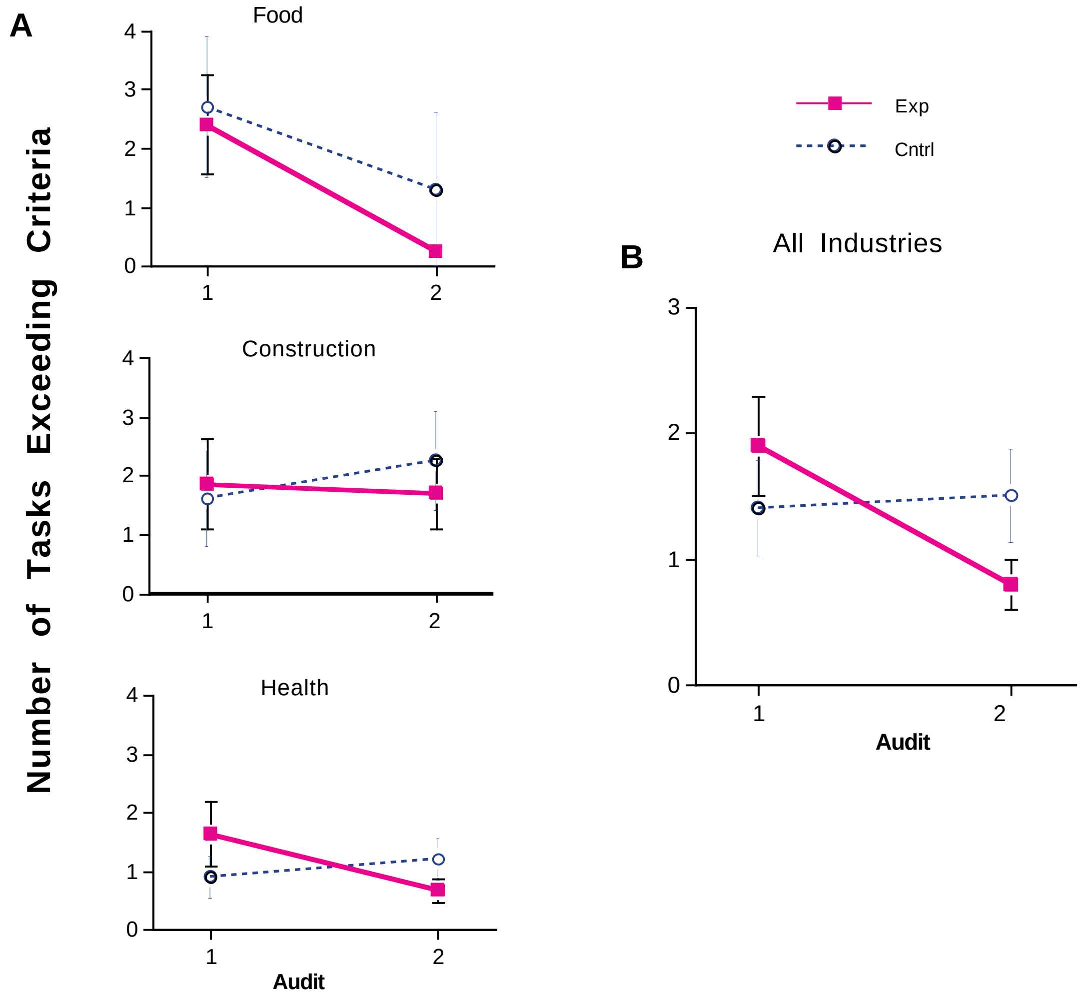

Figure 5: Workplace mean (+ SEM) number of tasks exceeding one or more action criteria by A) Group, Industry and Time and B) by Group and Time

Inspector Actions

The number of tasks for which action was actually taken is illustrated in Figure 6. The number of actions taken tended to increase for all groups in Audit 2, but less so for the Experimental groups. None of the effects reached significance with only Time ($F_{1,31}$ = 2.31, p = .139, partial eta^2 = .069), Industry ($F_{2,31}$ = 1.11, p = .342, partial eta^2 = .067) and Time x Group ($F_{1,31}$ = 0.73, p = .398, partial eta^2 = .023) showing small to medium effect sizes.

The relationship between the maximum cumulative score for any body region recorded for a task and whether inspectors took action or not is presented in Figure 7. The correlation between action and maximum cumulative risk score increased from 0.32 for tasks audited during Audit 1 to 0.49 for tasks audited in Audit 2.

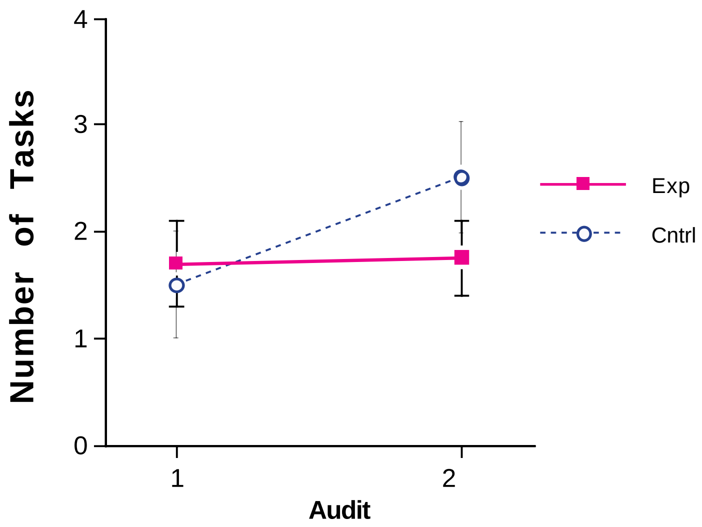

Figure 6: Workplace mean (+ SEM) number of tasks for which actions were taken by inspectors.

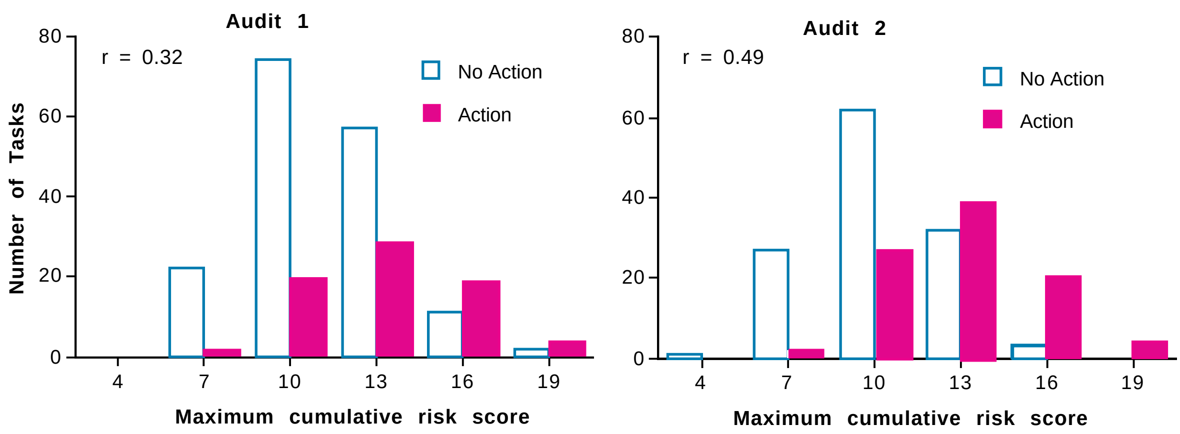

Figure 7: Maximum cumulative risk score for any body region as a function of inspector action and audit.

Procedural Activity

The levels of procedural safety-related activity from the employees' and managers' reports are shown in Figures 8 and 9. A Time x Industry x Group mixed model ANOVA for the number of safety activities reported by employees to have been undertaken in the past twelve months showed a significant main effect for Time ($F_{1,404} = 15.55$, $p < .001$), with employees reporting more activities in the 12 months before Audit 2 than in the 12 months before Audit 1. No other significant effects or trends relevant to the study were observed.

At Audit 2, managers were asked to indicate the number of manual task risk assessments and risk controls implemented since Audit 1. Investigation of Figure 9 indicates that the Experimental group conducted risk assessments on more tasks than the Control group. An Industry x Group ANOVA indicated that this trend, whilst not significant, reflected a small to medium effect size for Group ($F_{1,23} = .63$, $p = .437$, partial eta $^2 = .026$). Figure 9 suggests that the Control group implemented more controls than the Experimental group.

This effect was also not significant, and the effect size captured by this association was trivial (Industry x Group ANOVA, Group $F_{1,18} = .09$, $p = .764$. partial eta $^2 = .005$).

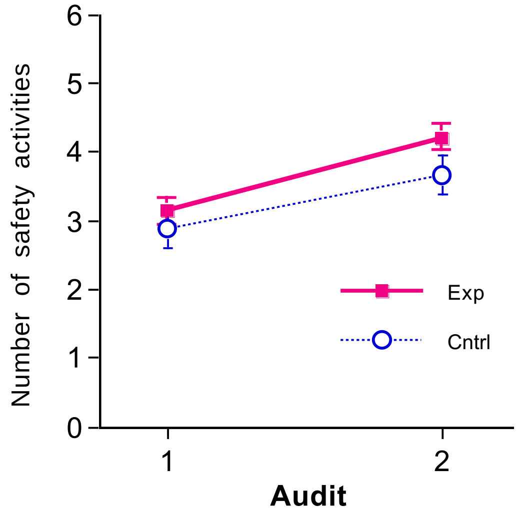

Figure 8: Mean (± SEM) number of safety activities reported by employees in Experimental and Control workplaces at Audits 1 and 2.

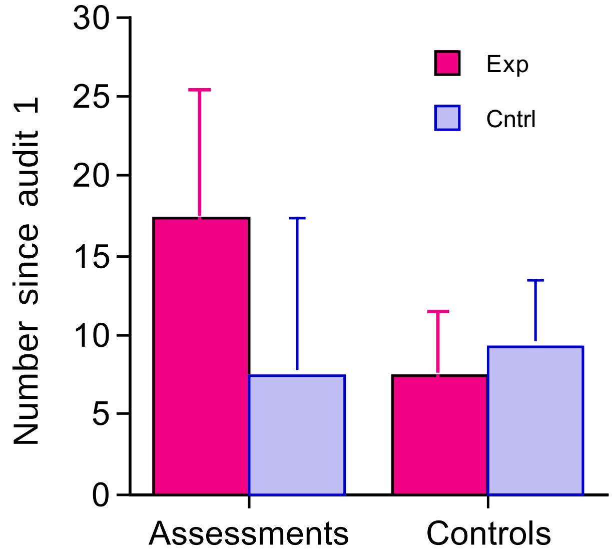

Figure 9: Mean (+SEM) number of manual tasks risk assessments and controls reported by managers in Experimental and Control workplaces at Audit 2.

Organisational Environment

There were three factors extracted from the supervisor data relating to management of manual tasks: allocation of responsibilities for general health and safety, allocation of responsibilities specifically for manual tasks and adequacy of training for health and safety and risk assessment responsibilities.

Figure 10 illustrates the mean values reported by supervisors for the allocation of general health and safety responsibilities in the Experimental and Control groups at Audit 1 and

Audit 2. The non-significant trend for allocation of responsibilities was for the Experimental group to have improved from Audit 1 to Audit 2 and the Control group to have deteriorated (Group x Time $F_{1,83} = 1.30$, $p = .257$ partial $eta^2 = .015$).

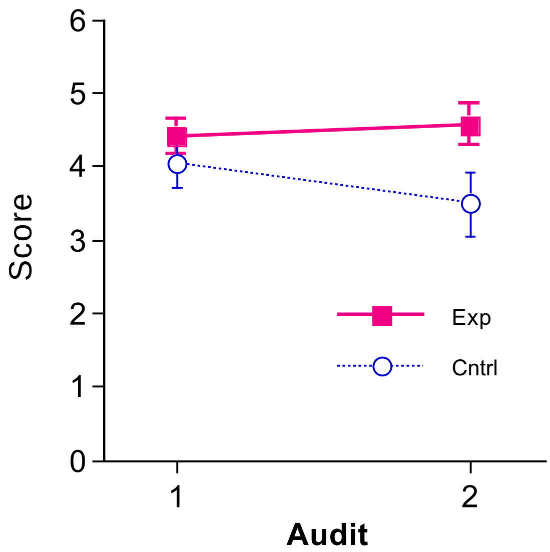

Figure 10: Mean (+ SEM) rating of quality of allocation of health and safety responsibilities to supervisors in Experimental and Control workplaces at Audits 1 and 2.

For allocation of manual task responsibilities, the three way interaction (Group x Time x Industry) was significant ($F_{2,78} = 4.629$, $p=.013$), thus separate ANOVAs for each Industry were run. In the Food group, there was a significant interaction between Group and Time ($F_{1,22} = 11.554$, $p= .003$, partial $eta^2 = .344$), illustrated in Figure 11a, b and c. There were no other significant Group x Time interactions for the Construction or Health groups, nor did the effect sizes indicate possible underpowered results (partial $eta^2 = .065$ for Construction and .007 for Health). Part of the reason for the lack of effect in the Construction and Food groups could have been due to a ceiling effect with this measure (the score could vary between zero and one).

The supervisors' perceptions of the adequacy of their training was notable for showing lower scores at Audit 2 than at Audit 1 ($F_{1,85} = 2.36$, $p = .128$, partial $eta^2 = .027$), but there was no trend for a Group x Time interaction ($F_{1,85} = 0.02$, $p = .897$, partial $eta^2 = .000$).

The purchasing officers provided information on two factors: sub-contractor risk assessment and internal risk assessment for new equipment. There were no significant effects of relevance from the intervention on subcontractor risk assessment (the extent to which contractors were part of the manual task risk assessment), but there was a significant Group x Time interaction for the internal risk assessment ($F_{1,75} = 6.81$, $p=.011$). The direction of this effect, however, was that the Control group showed an increase from Audit 1 to Audit 2, while the Experimental group showed a decrease, although the size of the effect was small to medium (partial $eta^2 = .083$).

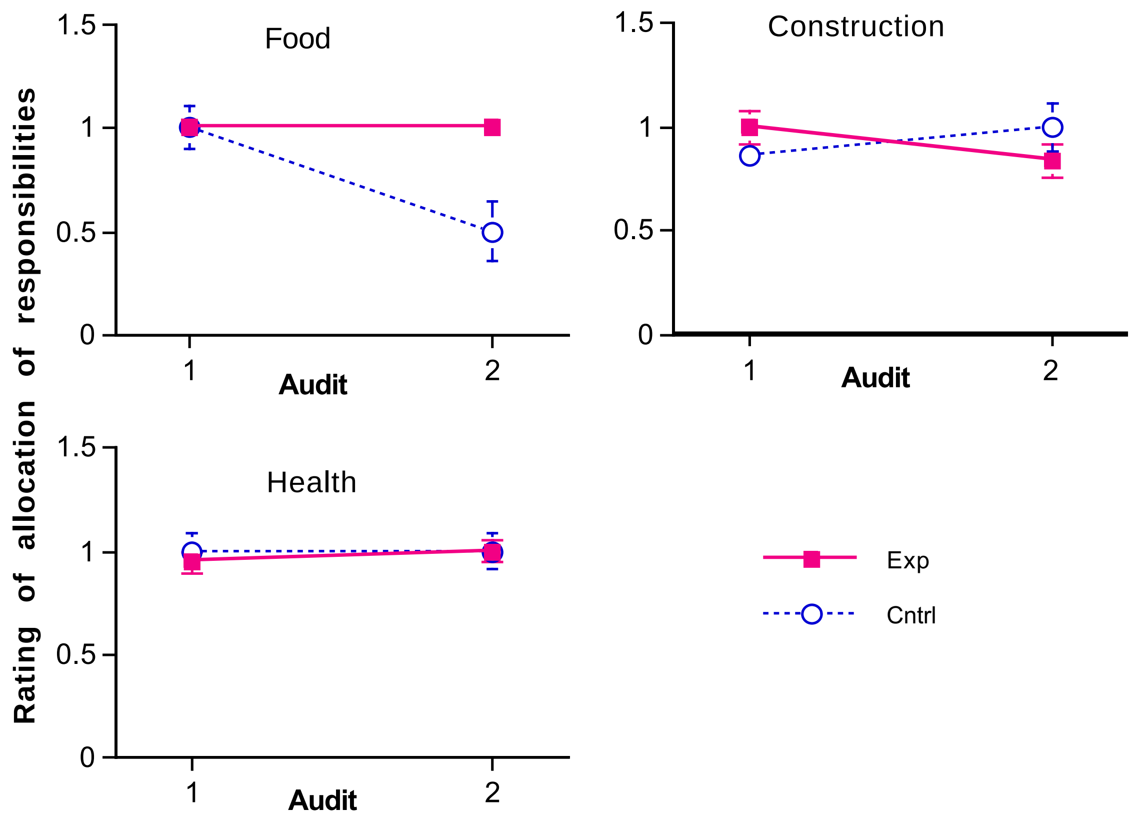

Figure 11: Mean (+ SEM) ratings of quality of allocation of manual task responsibilities to supervisor in Experimental and Control workplaces at Audits 1 and 2 for the Food, Construction and Health Industries.

The employees contributed data on factors relating to communication of health and safety policy via line management, communication of health and safety policy via health and safety officials, health and safety consultation representation, manual task risk management, training for manual tasks and incident and injury investigation. The communication of health and safety policy via line management showed a Time x Group x Industry three-way interaction, thus separate ANOVAs for each Industry were conducted. In Food there was no indication of an effect of the intervention, but in Construction and Health the Time x Group interactions approached significance (Construction: $F_{1, 76} = 2.97$, p=.089, partial $eta^2 = .038$; Health: $F_{1,206} = 2.94$, p=.088, partial $eta^2 = .014$). None of the other factors showed significant Group x Time interactions, or Group x Time x Industry interactions.

Discussion

Overall impact of PErforM

The results provide evidence that the PErforM intervention caused a reduction in estimates of manual task risks. The results also suggest that PErforM caused an increase in the risk assessment activity at a workplace, and an improvement in areas of the management systems supporting manual task risk assessment and control.

This study is the first randomised and controlled trial to evaluate a preventative participative ergonomics intervention for workplaces, and makes a major contribution to the field. The experimental design controls for important threats to the validity of causal claims. The study consequently provides high level evidence that it was the intervention which lead to the change in risk, and not some contemporaneous event such as a change in economic activity or government policy. Further, the number of workplaces involved, and their random allocation to the Experimental or Control group, ensured that the results were not dependent on individual workplace characteristics.

Impact on Manual Task Risk Estimates

The Total Assessed Risk Exposure clearly decreased for the Experimental group compared to the Control group (Figure 1) and this change was consistent for all Industry groups. The reduction in overall workplace risk for the Experimental group was a product of both a reduction in the number of tasks which inspectors considered needed assessment (Figure 2) as well as a reduction in the number of tasks which, when assessed, exceeded recommended thresholds (Figure 5).

Whilst the estimates of risk used in this study can be criticised for involving subjective judgements, no better assessment was available. Further, using government inspectors provided practical estimates of risk which have real legal and workplace ramifications.

Examination of the overall exposure to different risk factors suggests the intervention was more effective at reducing some types of risk (Figure 3). In particular, it seems that the intervention had the least influence on exertion risk factors, and greater effect on time based (task duration, cycle time) and awkwardness risk factors. This may be a consequence of a general awareness in the community of force as a risk factor, but less awareness of other risk factors. The intervention may therefore have had more effect on less well known risk factors. The effect of the intervention was fairly consistent across body regions, although to some extent this was a consequence of some time based risks being identical for all body regions (Figure 4).

The reduction in risk estimates in Experimental workplaces compared with Control workplaces was mirrored in inspector actions, with the Control group receiving more formal notices and advice than the Experimental group (Figure 6). This result highlights the practical outcome of the intervention in assisting workplaces to meet their legislative requirements to provide safe systems of work.

Taken as a whole, these results lead to a firm conclusion that the PErforM intervention was successful in reducing overall manual task injury risk. These data provide the best evidence to date to justify workplace based participative ergonomics interventions to reduce manual task injury risk.

Impact on Procedural Activity
Both Experimental and Control groups reported an increase in the number of safety activities related to manual tasks reported by employees, although the levels were still relatively low at Audit 2. While the increase was slightly greater for the Experimental group, this difference was not significant (Figure 8). This result suggests that the audit itself may have had an influence in increasing the number of manual tasks related safety activities undertaken.

While the employee-reported safety activity level was similar between groups at Audit 2, there was evidence that workplaces in the Experimental group had conducted more risk assessments than the workplaces in the Control group. This would be expected, given that the intervention included assisting employees to assess the manual task risk for a number of their tasks. What is puzzling is why the differences in manual task risk assessments reported by supervisors/managers was not reflected in changes in manual tasks risk assessments reported by employees in their answers on safety activity. Due to the sampling strategy in the Audits and intervention, some audited employees may not have participated in the training. It is also possible that employees may be unaware of the meaning of “risk assessment” in the procedural activity questions and mis-represented their activity, or that supervisors are mis-representing safety activity for some reason. Reports from the inspectors indicated that managers held a range views of what would count as a risk assessment, but given managers were aware that inspectors could require written evidence of the assessments conducted, we believe that the managers’ data are more likely to reflect the risk assessment practices in the companies involved.

The trend towards higher levels of risk assessment in Experimental groups was not sustained when the number of risk controls were analysed. In this case the Control group reported higher levels of controls than the Experimental group (although the effect size of this difference was trivial). In the light of the reduced physical task risk in the Experimental group, a higher number of assessments but similar number of controls illustrates an improved prioritisation of risk reduction approaches in the Experimental group. Further research into the quality of the controls implemented with participative approaches would be valuable.

Impact on Organisational Environment
The results of questions related to the organisational environment were notable in the lack of significant results from the factors derived from the employees, but the factors relating to issues to do with the supervisors/managers did indicate some effects. The trend was for better allocation of health and safety responsibilities in the Experimental group, and, except for ceiling effects in two industries, better allocation of responsibilities for manual tasks. Both of these would indicate an improvement in the management system in the Experimental group. The general decrease in perceived adequacy of training and knowledge for their health and safety responsibilities for both groups between Audit 1 and 2 may be indicative of a general increase in understanding of what they *should* know for these tasks. The fact that both groups showed this decrease may represent an effect of the initial audit on supervisors’ satisfaction with their own knowledge, or an impact of media campaigns relating to this factor between the times of the two audits.

The only employee derived factor that indicated an experimental effect was in the provision of health and safety information from the line management. This effect is consistent with the improvements in line management of health and safety responsibilities observed from the factors derived from the supervisors and managers. It is of interest to know why other factors relating to employees did not show experimental effects, but it is notable that the procedural safety measures also indicated that employees' responses were not impacted by the experimental intervention, whilst the management systems were effected. The employee factors were responsive to other factors with several showing changes between Audit 1 and 2 or differences between industries, thus suggesting that the measure itself was not insensitive to change.

Ultimately any program of this nature would wish to see changes in the employees' reports of the quality of the management system. However, given the length of the intervention, the fact that the top levels of management were being impacted is possibly of more import. The more aware the managers and supervisors of an organization are to how best to manage manual task risk, the greater the potential for long term change. In the shorter term, it may be that employees' are impacted in other ways. A qualitative analysis of interviews with employees and their supervisors is currently being completed to determine employees' perception of how they feel about their work and their control over their work.

Industry Differences

The risk scores for wrist/hand and shoulder/arm and repetition risk were higher for the Food workplaces than for other industries, as would be expected given common food processing tasks. The lower back risk scores for the Health workplaces is likely to reflect the strong push in recent years in Queensland towards "no lift" policies in health care organisations, and the incorporation of such requirements into aged care accreditation procedures.

The increase in total cumulative risk in both Construction groups is puzzling. Due to the introduction of increased taxation on building in July 2000, the construction industry was in 'boom' at Audit 1, whereas it was near 'bust' during Audit 2. We initially wondered whether the rise in average task risk ratings represented a reduction in safety standards to ensure economic survival. However this increase was not industry wide as we were able to compare to other audit data from workplaces outside South-East Queensland, and the non volunteer workplaces. One possible explanation came from inspectors during post Audit 2 evaluations. They reported becoming aware of workplaces which had actively hidden high risk tasks from inspectors. In one extreme case a workplace had shut down a whole production section so that high risk tasks could not be evaluated by inspectors. It was thought that Experimental and Control (because they knew they were getting the intervention soon) may have felt less need to hide risk tasks in Audit 2.

Significant differences in work practices, workforce characteristics and culture exist between industries. These are being evaluated in the related investigation of how the intervention was implemented and what characteristics of a workplace encouraged successful outcomes.

Use of ManTRA

The inspectors' use of ManTRA changed slightly from Audit 1 to Audit 2. The relationship at a task level between inspectors actions and the maximum cumulative risk score for any body region as a function of audit time (Figure 7) indicates that the inspectors were more likely to take action (issue formal advice, or improvement or prohibition notices) in the second round of audits for tasks of similar risk. Focus group and questionnaire data gathered from inspectors following Audit 2 suggests that this change is likely to reflect greater confidence and experience in auditing for manual task risks. A key purpose of the ManTRA tool had been to assist inspectors to make judgements about actions. Inspectors had previously been reluctant to take action against high risk manual tasks as illustrated by very few prohibition or improvement notices being issued for manual tasks risks in the previous 7 years.

However the assessment of risk of injury due to manual tasks was not mechanical, and the judgement of the government inspectors played a key role. The selection of tasks for assessment was driven by the information obtained by the inspectors during their interviews of employees, their observations of the workplace, and their knowledge of the industry. Inspectors were asked to assess the same number of tasks in each workplace of comparable employee numbers. However inspectors tended to only proceed with a task assessment when their initial impression was that the task was high risk. This resulted in the comparison of total cumulative risk (Figure 2B) suggesting little difference between groups. However the change in the number of tasks assessed and the number of tasks exceeding thresholds captured the reduction in risk following the intervention.

Given our experience with an audit based on task sampling we believe it is not the optimal approach to evaluate actual risk and organisational initiatives to reduce risk. We have recommended to the government authority involved that future audits focus on the management system for risk assessment and control. Queensland legislation already requires documentary evidence of risk management activity and this evidence can form the basis of a more systematic audit. Such an audit would have the advantage of not being as open to manipulation by workplace management. For example workplaces couldn't arrange for inspectors to come during quiet production time, nor could they hide high risk tasks by closing parts of the workplace.

Study Limitations

Whilst this study represents the first randomised and controlled trial of participative ergonomics at a workplace level, some limitations need to be considered in evaluating the results.

The average number of tasks assessed in Audit 1 for each Experimental workplace (6.8) was greater than for the Control group (4.6). Our randomisation process was stratified for the 3 industry groups, but not for the number of tasks assessed. At Audit 2 the average number of tasks for each Experimental workplace had fallen to 4.5, whereas it had risen slightly for the Control group (4.9). Audit 1 data were not available to the investigators at the time of allocation and we had anticipated that the random nature of the allocation would have provided more similar groups. It could be argued that the reduced number of tasks assessed in the Experimental group was a regression towards the mean. However the remaining data suggest there was a real reduction in the inspector assessment of risk in Experimental workplaces.

At Audit 1 the inspectors and workplaces were blind to the group allocation (the random allocation to intervention was performed after the audit). It was intended that the inspectors would be blind to the group allocation at Audit 2 also. However the Experimental and Control workplaces could not be kept blind to their participation and on occasions they discussed workplace interventions with inspectors during Audit 2. This was discovered during focus group evaluations with inspectors following Audit 2. However it was also discovered that some Control workplaces had attempted interventions of their own (sometimes with external ergonomics assistance) and the inspectors thought some of the Control workplaces were Experimental workplaces. Any bias is consequently likely to have tended to obscure rather than amplify group differences, suggesting that the real effect of the intervention may be larger than reported. Similarly, our analysis was on a conservative 'intention to treat' basis, further minimising the risk of falsely identifying an intervention effect. Analysis of the quality of the implementation at some workplaces is being conducted.

We are confident that there was no systematic bias in the allocation or assessment of the groups, and that there was a real reduction in manual task risk and a change in the relative management systems at Experimental workplaces compared with Control workplaces.

PErforM Intervention
Several aspects of the PErforM intervention were different to traditional prevention interventions.

PErforM was designed to have minimal interference with normal workplace activities. The total time required of workers (about 4 hours including "homework'' activities) was much less than other reported interventions. For example, Morkden et al.'s (2002) intervention required 20 hours. The PErforM intervention was aimed at making easy changes to workplaces to control obvious manual task risks. Based on our prior experience (Straker 1990) we believed that significant risk reductions could be achieved with a small organisational investment, and the results of this study support this. It is hoped that, having seen the success of the small investment, workplaces will make further investments.

PErforM only addressed *prevention* of musculoskeletal disorders. Over the previous decade Australian authorities and organizations have substantially improved their occupational rehabilitation process (Innes & Straker 2002). The focus on early, managed return to work has resulted in reductions in the cost and other impacts of injuries on workers and their organizations. Our interest was therefore on prevention alone, rather than prevention in combination with rehabilitation as investigated by Morkden et al. (2002) and Loisel et al. (1997).

Major components of traditional prevention activities have been teaching spinal anatomy and lifting technique training. We believe, however, that knowledge of anatomy is not essential for effective manual task risk management and that time is better spent on risk assessment and control skills. The evidence supporting the correctness of a particular lifting technique is also equivocal (Burgess-Limerick 2003; Straker in press) and teaching lifting technique is clearly not effective in reducing musculoskeletal risk (eg., Daltroy et al. 1997). Consequently, the PErforM intervention contains no lifting technique training but rather focusses on developing effective risk assessment and control skills in workers, and effective management systems within the workplace.

Whilst there was some evidence from prior experience that participative ergonomics for work teams could result in significant change (Straker 1990), the impact of these interventions had rarely been sustained. It is likely that the best way to encourage sustainability is to imbed the process of manual task risk assessment and control within each organization's management systems. A major component of PErforM was therefore the assistance provided to managers to develop appropriate policies, procedures and allocated responsibilities. Further long term follow up is required to evaluate whether this assists sustainability.

Intervention Process
The success of the intervention in the current study was not uniform. A concurrent qualitative review of the process of implementing the intervention was undertaken to understand why the intervention was more effective in some workplaces than others. This part of the project involved in depth interviews with workers, supervisors and managers at selected workplaces and with the ergonomics consultants. Analysis of this rich data is currently underway and aims to characterise those workplaces where participative ergonomics was most successful. We believe this will lead to the development of guidelines for interventions which include a set of necessary precursors for an organization to achieve prior to implementing PErforM or similar participative ergonomics programs.

Application of Randomised and Controlled Trial Designs in Ergonomics
In the 1990s ergonomics struggled to demonstrate that it was worth the community and organisational investment of resources. The prolonged struggle to develop and implement a national US standard to reduce the risk of musculoskeletal disorders associated with manual tasks was a significant example of the difficulties associated with the lack of evidence from adequately controlled studies. Randomised and controlled trials are the study designs which provide the highest level of evidence. The resource and logistic requirements of conducting a randomised and controlled trial with an ergonomics intervention are enormous compared to their traditional use in evaluating medication interventions. However this high level of evidence is required to better persuade governments and workplaces. It is hoped that the success of the current trial will encourage other ergonomics research groups and organizations to attempt further randomised and controlled trials.

Conclusion

This paper has reported on a study of major significance to the practice of ergonomics internationally. The study was the first randomised and controlled trial of participative ergonomics aimed at preventing musculoskeletal disorders associated with manual tasks applied to whole workplaces. As such, it represents the highest level of evidence evaluating the efficacy of preventative ergonomics.

The results of this randomised and controlled trial have demonstrated that a participative ergonomics intervention can be effective in reducing the risk of musculoskeletal disorders at a workplace. This evidence will enable ergonomists to more convincingly argue the wisdom of implementing ergonomics standards to government agencies. The evidence will also enable ergonomists to more convincingly present a case to managers that it is in an organisation's best interests to invest resources in participative ergonomics.

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APPENDIX A

PErforM Program Outline

The Program involves four visits to the workplace by a PErforM consultant. Following acceptance into the program, the manager will be contacted by a consultant to arrange the first visit. Subsequent visits will be scheduled during the management briefing during the first visit. The exact content of each contact may be modified to suit the requirements of the individual workplaces, but the following will constitute a typical arrangement.

Visit 1: *Management briefing and workplace familiarisation*. The consultant will provide the manager with a thorough briefing regarding the training to be provided to staff; negotiate with the manager how the training may be delivered with minimum disruption to the workplace; and discuss the most appropriate way of assessing workplace performance (1 hour). The consultant will be escorted through the workplace to gain an appreciation of the details of the workplace (1 hour). The consultant will also provide the manager with information explaining the program which is suitable for distribution to staff.

Visit 2: *Management systems, supervisor and WHSO briefing, videotaping tasks*. The consultant will assist the manager, or delegate, in the development/improvement of OH&S management systems (2 hours). This will incorporate discussion of the results of the DWHS manual tasks audit. The consultant will then provide a briefing to supervisors of the work teams which will be involved in the training, and to Workplace Health and Safety Officers. This briefing will provide the supervisors with information regarding the management systems and content of the training (1 hour). The consultant will request assistance from the supervisors in identifying relevant manual tasks suitable for videotaping (1 hour). The objective is to obtain workplace specific illustrations to utilise in subsequent training.

Visit 3: *Risk management training*. The core of the PErforM program is training of 1-3 intact work teams in manual tasks risk management. The training focuses on meeting the requirements of the manual tasks advisory standard and incorporates video of specific workplace tasks (1-3 work teams x 90 minutes). Questionnaires assessing group cohesion, work group characteristics and safety climate will also be distributed to each worker at this session.

Between visits 3 & 4 each work team will be asked to conduct and document a manual tasks risk assessment of selected tasks within their workplace and to suggest control measures.

Visit 4: *Work team debriefing.* The final visit involves a review of the risk assessments conducted by each work team to provide feedback regarding the assessments and control measures suggested (1-3 teams x 90 minutes).

Reports: The consultants will document each visit as part of the process evaluation.

Workplace follow up: The PErforM consultants will be available for further assistance for a limited time following the program delivery. Other sources of further assistance will also be provided.

Evaluation Interviews: The evaluation process also requires interviews with management, supervisors and staff on (at most) three occasions at 3 monthly intervals in the nine months following the implementation of the program. The purpose of these interviews is to evaluate the program and determine how the process might be improved, not to evaluate the workplace.

APPENDIX B – Manual Task Risk Matrix

			Task Codes							CumulativeRisk
Body Region	Total time	Duration	Cycle time	Repetition Risk	Force	Speed	Exertion Risk	Awkwardness	Vibration	
Lower Limbs										
Back										
Neck										
Shoulder/ Arm										
Wrist / Hand										

Cumulative risk is the sum of unshaded cells.

Codes

Total time

1	2	3	4	5
0-2 hours/day	2-4 hours/day	4-6 hours/day	6-8 hours/day	> 8 hours/day

Duration of continuous performance

1	2	3	4	5
< 10 minutes	10 min - 30 min	30 min - 1 hr	1 hr - 2 hr	> 2 hr

Cycle time

1	2	3	4	5
> 5 minutes	1 – 5 minute	30 s - 1 min	10 s - 30 s	< 10 s

Force

1	2	3	4	5
Minimal force		Moderate force		Maximal force

Speed

1	2	3	4	5
Slow movements	Moderately paced	Little or no movement – static posture	Fast and smooth movements	Fast, jerky movements

Awkwardness

1	2	3	4	5
All postures close to neutral	Moderate deviations from neutral in one direction only	Moderate deviations in more than one direction	Near end range of motion posture in one direction	Near end range of motion in more than one direction

Vibration **(Whole body or Peripheral)**

1	2	3	4	5
None	Minimal	Moderate	Large amplitude	Severe amplitude

Scoring Keys for Repetition & Exertion

Scoring key for Repetition

			Duration		
Cycle Time	***1***	***2***	***3***	***4***	***5***
1	1	1	2	3	4
2	1	2	3	4	4
3	2	3	3	4	4
4	3	3	4	4	5
5	3	4	4	5	5

Scoring key for Exertion

			Force		
Speed	***1***	***2***	***3***	***4***	***5***
1	1	1	2	3	4
2	1	2	3	4	4
3	2	3	4	4	5
4	2	3	4	5	5
5	3	4	5	5	5

Action may be indicated if, for any region, the Exertion risk factor is 5, the sum of exertion and awkwardness is 8 or greater, or the cumulative risk is 15 or greater