Task Rotation in an Underground Coal Mine: A case control study.

Results for Mandalong, Springvale and Comparison between both sites.

November 2017

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Acknowledgements

This study has been undertaken with the support of researchers from the University of Newcastle and from Coal Services Health. The Investigators include:

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We also acknowledge the commitment and support of Mandalong and Springvale mines their management teams, and mine employees who have willingly given their time and energy to support this research.

This research project was possible as a result of industry partnerships and aimed to address an industry-identified need. Such partnerships must be collaborative with both sides sharing in the creation of research questions, methods and interventions. Without such industry partnerships, ensuring the success of research and the building of evidence around the implementation and sustainability of interventions and programs would be very difficult.

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24 November 2017

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1 Executive Summary

Task rotation is a workplace intervention used to decrease the risk of workplace injuries and improve work satisfaction. This case control study built upon the pilot study that was completed in 2015, which investigated the feasibility, benefits and challenges of implementing a task rotation schedule within an underground coalmine. The pilot study found that rotation between tasks twice or three times during a shift, was feasible and practical in the dynamic environment and there was some improvements in the psychological and environmental domains of the quality of life measure.

This study aimed to investigate the physical and psychological effects and challenges to implementing a task rotation schedule at a whole of site level in an underground coal mine, by comparing this to a control site where duties are completed 'as normal'.

Task rotation was implemented across the entire site at the Mandalong underground coal mine. Data was collected from surveys administered to participants at the Intevention site (Mandalong) and the Control site (Springvale) at commencement of the study (Baseline; Phase 1), mid-way through the study (Phase 2), and at the conclusion of the study (Phase 3). In addition, a task rotation log was collected at the Intervention site detailing the tasks and rotations achieved during the 12 month period, and injury statistics were provided and also analysed. Comparisons between the phases for each site and comparisons of Phase 1 and Phase 3 between the Intervention (Mandalong) and Control (Springvale) sites were completed.

There was no significant difference in psychological distress scores at Phase 1 or Phase 3 between Intervention (Mandalong) and Control (Springvale). This indicates that the intervention did not have an effect on psychological distress.

In relation to fatigue, the mean fatigue scores increased at the Intervention site (Mandalong) over the study period with a significantly higher average level of fatigue reported at the conclusion of the study (Phase 3) when compared to the Control site (Springvale). This may be explained by the introduction of the task rotation, with the effectiveness of task rotation being dependent upon how biomechanical stressors are balanced and the specific rotation scheme.

In the Intervention (Mandalong) site where a weekly log of task rotation was kept, tasks in the Development location were most commonly rotated three times per shift, whereas in the Longwall location tasks were most commonly rotated only twice per shift. The amount of rotation however varied according to the shift, with some shifts logging more rotations than others, which suggests that some crews, on some shifts were more committed to the process of task rotation. When considering the individual workers on each shift there was less data available to analyse with two rotations on average per worker in the Development location being completed on all shifts with the exception of the longer weekend day shift where three rotations were more commonly achieved per worker. On the Longwall location, this was more commonly on average one task per person, except on the longer weekend shifts when this was on average two tasks per worker. This raises the question as to whether some of the workers were taking longer periods of time doing the one task than others to achieve this result. However, overall the amount of task rotation achieved was less than that recommended for task rotation to be effective. Therefore the actual schedule of rotation, and the implementation and execution of the schedule, may need consideration and potential review to assist in effectively controlling injury and fatigue risk.

There were no differences in Quality of Life (QOL) scores between the two sites over the study period. Both sites reported a reduction in Physical and Environmental domain scores of the QOL at the conclusion of the study, and increase in scores in the Psychological domain with the Social Relationship domain scores remaining fairly constant. This suggests that the task rotation did not have a significant impact upon QOL. However when comparing participants' QOL scores to the Australian norms, at all-time points during the study the QOL scores at the Intervention (Mandalong) and Control (Springvale) sites were below that of the Australian norms for each of the four domains.

When comparing the musculoskeletal discomfort reported between the two sites there was no significant differences identified. However, reported musculoskeletal discomfort reduced between Phase 1 and Phase 3 at the Intervention site (Mandalong) in all body regions except the neck. There was also a significant difference identified at the Intervention site (Mandalong) between the Development, Longwall and Other locations of the mine in relation to knee discomfort. This may be related to the different floor conditions, or, the tasks completed in the different sections of the mine. The Other work location had the highest reported knee discomfort and it should be noted that this is one area of the mine that a task rotation schedule log was not recorded. There was a reduction in the number of reported musculoskeletal discomfort as a result of a work related cause at both sites over the duration of the task rotation intervention, however no significant difference between the Intervention (Mandalong) and Control (Springvale) site. There was a reduction in reported discomfort over the course of the task rotation in the left shoulder, which corresponds with a reduction in discomfort reported as owing to both a non-work related and work related accidents at the Intervention (Mandalong) site. Alternating tasks that involve shoulder activity such as bolting tasks within the Development unit may have influenced this outcome with less musculoskeletal discomfort reported specifically in the left shoulder over the course of the task rotation period. At both sites the lower back, knee, neck, shoulders and ankle were the most commonly reported regions to experience discomfort.

Injury rates at the Intervention site (Mandalong) were similar pre- and during the task rotation period, with the most common injury being to the knee. This corresponds with the findings of the study, where reported knee discomfort was significantly higher Phase 3 compared to Phase 1. In addition, a larger percentage of participants reported knee injury as a result of a work related cause.

There were no significant differences between the Intervention site (Mandalong) and the Control site (Springvale) on the Job Content Questionnaire (JCQ) aspects of skill discretion or discretion authority. However, there were significant differences between the psychological demands aspect of the JCQ at both Phase 1 and Phase 3 when comparing the two sites, specifically in the low and moderate ranges with the Intervention site (Mandalong) reporting more participants in the low range. As there were differences both at the beginning and end of the task rotation, these results are unlikely to have been influenced by the intervention.

The findings from this study need to be considered in light of the limitations. The detail of the amount of task rotation that was actually implemented at the Intervention site was limited by the completion of the task rotation logs with some shifts having more data to analyse than others. The amount of rotation however varied according to the shift, with some shifts logging more rotations than others, which suggests that some crews, on some shifts were more committed to the process of task rotation. It is however, acknowledged that doing ‘implementation research’ in a real workplace environment, particularly an environment as dynamic as an underground coal mine is very challenging.

The actual schedule of rotation, and the implementation and execution of the schedule, may need consideration and potential review to assist in effectively controlling injury and fatigue risk. In addition, supplementary research with a more structured task rotation process would be beneficial to improve validity of these findings.

2 Introduction

2.1 Background

Working in an underground coal mine typically involves physically demanding work and requires workers to complete a range of manual handling tasks that involve repetitive lifting, carrying, pushing and pulling in a variety of work conditions. In underground coal mines, the ground surface may be uneven, muddy or wet, and miners may be subjected to poor lighting and loud machinery (1). Eemployees' wear a heavy belt with safety equipment attached, a hard hat with a lamp and steel-cap waterproof boots throughout their shift underground (1). These manual handling tasks and working conditions can lead to fatigue and musculoskeletal injuries. Globally, the mining industry has improved its safety standards dramatically over the past few decades as a result of advancements in mining techniques and machinery, improved health and safety standards and increased worker education and training (2). Over the last decade, the introduction of new technology, along with heightened concerns for safety, has resulted in significant reductions in injury rates. Despite this, mining still ranks high amongst the formal economy sectors for work related fatalities, injuries and illnesses (2). Epidemiological studies of population groups in Australia, New Zealand and the United States have reported fatal injury rates 7 to 10 times higher among mining workers than that of the average worker (3). Between 2001-02 to 2014-15, body stressing due to handling, carrying and putting down objects, represented 39% of all worker's compensation claims in the Australian mining industry (4). Falls, trips and slips accounted for 25%, followed by 18% involving impact by a moving object (4).

2.2 Task Rotation

Task, or job rotation, is a method used to regularly alternate workers between differing tasks or workstations, with each rotation requiring different skills and responsibilities (5, 6). It is commonly used as an intervention to minimise the accumulated biomechanical stress associated with repetitive muscular loading (5, 7, 8). Multiple studies have identified benefits of task rotation, describing it as a useful tool in decreasing the risk of work-related musculoskeletal injuries, increasing work productivity, limiting worker boredom and fatigue, increasing employee satisfaction and reducing worker error (5, 6).

A task rotation schedule should consider the sequence and physical demands of each task, as well as the frequency of rotations (6, 9, 10). Ideally, task rotation schedules rotate through low and high demanding jobs, as well as the different types of jobs (7).

Previous studies completed on task rotation have found mixed results regarding its effectiveness as a workplace intervention (11). Task rotation in refuse collecting environments has been investigated by a series of studies. The findings detailed that when task rotation schedules were implemented, cardiovascular loads and non-neutral working postures were reduced for employees (12-14), although an increase in the number of lower back pain complaints was seen (14). This may be a consequence of the rotation schedule distributing physical loads between employees, resulting in an increase in the number of workers exposed to heavier loads (14). Results of a job rotation intervention in a meat-cutting department showed it was positively regarded by the majority of employees, and demonstrated a reduction in the overall level of the physical and mental tiredness of employees. Although task rotation is a popular workplace practice, there is inconsistent evidence in the literature to support its use. Despite this, Padula *et al* (15) in their systematic review of task rotation in manufacturing industries, highlighted that through evaluation of organisational factors, task rotation had a high approval rating from trained workers. It was detailed that rotating tasks enabled workers to complete tasks with more confidence and increased job satisfaction (15).

Although task rotation is a popular workplace practice, its impact on reducing work related injuries and improving work productivity is not well defined (7, 14), especially in the coal mining industry. Furthermore, the majority of the studies completed on task rotation have been conducted in either a controlled laboratory environment or within an industry where work tasks are controlled and predictable. Underground coal mining is a dynamic and unique occupation with little evidence available describing the use of task rotation.

In a small pilot study designed to assess the feasibility of implementing a task rotation intervention in an underground coal mine, it was found that rotation between tasks twice or three times during a shift was feasible and practical in this dynamic environment. Improvements in the psychological and environmental domains of the quality of life measure were also found (16). Interviews with a small group of those who participated indicated that the intervention was also viewed positively by crew and management (17).

2.3 Aim

This study aims to investigate the physical and psychological effects and challenges to implementing a task rotation schedule at a whole of site level in an underground coal mine, by comparing this to a control site where duties are completed ‘as normal’.

3 Methods

Task rotation was implemented across the entire Intervention site (Mandalong underground coal mine) and was evaluated at three time-points across a 12 month period. Data from the Intervention site (Mandalong) was compared to data collected from the Control site (Springvale). At the Control site (Springvale), the work routine continued as normal over the 12 month period.

Data was collected from surveys administered to participants at both locations at commencement of the study (Baseline; Phase 1), mid-way through the study (Phase 2), and at the conclusion of the study (Phase 3).

3.1 Recruitment

Participants were recruited from Centennial Coal underground operation sites at Mandalong in the Newcastle Coalfields, and Springvale in the Western Coalfields of New South Wales. All employees at both sites were eligible to participate in this research.

3.2 Ethics

Potential participants were provided with verbal and written information regarding the study. Consent to participate in the survey was voluntary. A study code was used in place of participants' names throughout the study period to enable data tracking and maintain participants' confidentiality. All data was de-identified and stored securely on a password protected electronic database accessible only to members of the research team. Completed questionnaires were stored in a locked filing cabinet where data will be retained for five years beyond the publication of any data arising from this study.

Human ethics approval was granted from the University of Newcastle Human Research Ethics Committee prior to commencing this study (approval number: H-2015-0016).

3.3 Data collection

A paper-based survey was administered to participants at the beginning of shift at both sites at the start of the study (Baseline; Phase 1), at the 6 month point of the task rotation intervention (Phase 2) and at the 12 month point of the task rotation intervention (Phase 3). Staff from Coal Services Health attended sites at the beginning of shift to distribute and collect the paper-based surveys. The Phase 1 and Phase 3 survey contained a section on general demographic information, and five self-administered assessment tools: the Nordic Musculoskeletal Questionnaire (18), the Need for Recovery after Work Scale (19), Psychological distress Scale (20), Job Content Questionnaire (21), and the Australian WHOQ-BREF (22). The Phase 2 survey excluded the Nordic Musculoskeletal Questionnaire (due to the time period).

3.4 Survey

General information: Nine questions covering demographic information (e.g. date of birth, height, weight) and workplace information (e.g., location of work, shift, current role).

The Nordic Musculoskeletal questionnaire (18): A forty item assessment tool that provides a comparison of low back, neck, shoulder pain and general complaints. This assessment was used to gather information on the participants' musculoskeletal symptoms throughout the study period.

The Need for Recovery after Work Scale (19): An 11-item dichotomous questionnaire which assists in quantifying the respondent's severity of symptoms relating to work-related fatigue (e.g. I find it difficult to relax at the end of a working day). Scores are represented from 1 – 100, with higher scores indicating a higher degree of need for recovery after work. A validation study reported excellent test□retest reliability for the scale, sensitivity to detect change and therefore useful for evaluating occupational healthcare interventions (19). Lower fatigue scores indicate lower levels of fatigue.

Psychological distress (K10) (21): A ten item questionnaire designed to measure psychological distress. Each question is answered on a 5-level response scale according to emotional states experienced in the last four weeks. The K10 is scored by allocating one mark to answers of 'none of the time' through to five marks for 'all of the time', thereby creating a total score that may range from 10 to 50. Higher scores indicate a higher association with a diagnosis of anxiety or affective disorders (23). K10 scores are further stratified into four categories of low (10-15), moderate (16-21), high (22-29) and very high (30-50). These categories were then further summarised into two overarching K10 scores of low/moderate (10-21) and high/very high (22-50).

Job Content Questionnaire (JCQ) (21): The survey used a modified version of the JCQ to determine a perceived ratio between job demands and job resources. Scores were further stratified within categories reflecting answer descriptions. Skill Discretion scores ranged between 0 – 16 and were stratified into very low (0 – 7), low (8 – 11), moderate (12 – 14) and high (15 – 16). Decision Authority and Psychological Job Demand scores ranged between 0 – 12 and were stratified into very low (0 – 6), low (7 – 8), moderate (9 – 10) and high (11 – 12). Job Support scores ranged between 0 – 8 and were stratified into very low (0 – 2), low (3 – 4), moderate (5 – 6) and high (7 – 8).

Previous research has shown that a perceived imbalance of the job demands and job resources are an important determinant of workplace stress.

The World Health Organization Quality of Life Instrument-Abbreviated Version (WHOQ-BREF) (22): A 26 item standardised questionnaire that assesses QOL within the context of an individual's culture, value systems, personal goals, standards and concerns, and is divided into four domains of physical, psychological, social relationships and environment (22, 24). The questionnaire provides a QOL score across these domains (see Table 1) and has been shown to have high validity and reliability (24, 25). The WHOQ-BREF domain scores range between 0 – 100. The domains of the WHOQ-BREF are positively scored; with higher scores indicating higher levels of QOL. The environment domain of the WHOQ-BREF encompasses the participants′ physical environment as well as their financial resources, health and social care, and opportunities for acquiring new information and skills (22).

Table 1 – WHOQ-BREF domains

Domain	Facet	Example Questions
Physical	Pain and discomfort, energy, mobility, activities of daily living and work capacity.	Do you have enough energy for everyday life? How satisfied are you with your health?
Psychological	Positive and negative affect, thinking, learning, memory and concentration, body image and self-esteem.	How much do you enjoy life? To what extent do you find your life to be meaningful? How well are you able to concentrate?
Social	Relationships and social support.	How satisfied are you with your personal relationships? How satisfied are you with the support you get from your friends?
Environmental	Safety and security, physical environment, financial resources, opportunities for acquiring new information and skills, participation in and opportunities for recreation/leisure activities, home environment and health and social care.	Do you have enough money to meet your needs? How satisfied are you with your access to health services? How healthy is your physical environment?

3.5 Weekly schedule of task rotation (Intervention site)

A record of the weekly schedule according to the rotation of the main tasks was kept for each crew at the Intervention site (Mandalong). At the Development location, the tasks were: continuous miner driver, right bolter, left bolter, left hand off-sider, shuttle car and supplies. At the Longwall location the tasks were: shearer driver, chock operator (x2), boot-end attendant and trades. Between two to three task rotations across each shift were documented throughout each week to allow an analysis of the rotation between crew members across the various tasks.

3.6 Data analysis

Data from the questionnaire were entered into a database and analysed using Stata/SE 14.1 (26). Initially, bar chart and descriptive statistics (mean, standard deviation, and confidence interval) were used to explore the demographics and work-place characteristics of the participants for the sample at each Phase. Mean fatigue score (with 95% confidence interval) was calculated based on the responses from the ‘Need for Recovery After work’ scale, with a lower score indicating a lower level of fatigue. To determine the mental health problems of participants, psychological distress scores were calculated from the 5-level response scale (ranging from ‘None of the time’ to ‘All of the time’) of the K10, and then stratified into four categories of low (10 – 15), moderate (16 – 21), high (22 – 29) and very high (30 – 50). Bar charts illustrate the proportion of participants at each category of psychological distress, and compared between Phase 1 and Phase 2; between Phase 1 and Phase 3; between Intervention site (Mandalong) and Control (Springvale); and with Australian (employed) data along with other mine data. Additionally, two-sample proportional tests were also applied to examine whether there were any significant differences between Phase 1 and Phase 2; and Phase 1 and Phase 3 at the Intervention site (Mandalong); Phase 1 and Phase 2; and Phase 1 and Phase 3 at the Control site (Springvale); and differences between Phase1 and Phase 3 when comparing Intervention site (Mandalong) and Control (Springvale). Individual participants’ ‘Nordic Musculoskeletal Questionnaire’ and ‘WHOQOL-BREF’ assessment scores were calculated as per the respective guidelines (19, 22). WHOQOL-BREF score calculations for the four domains (physical, psychological, social relationships and environment) were calculated with a higher score indicating a higher level QOL. Mean score and standard deviations were calculated for each domain and two-sample t-test was used to examine whether any significant differences of mean QOL scores between Phase 1 and Phase; and Phase 1 and Phase 3 at the Intervention site (Mandalong); Phase 1 and Phase 2; and Phase 1 and Phase 3 at the Control site (Springvale); and differences between Phase1 and Phase 3 when comparing the Intervention site (Mandalong) and Control (Springvale). The weekly schedule of task rotation information at the Intervention site (Mandalong) was input into a data spreadsheet for analysis to allow proportions of rotations of the different tasks to be calculated. The proportions were tested at p <0.05 level of significance.

4 Results

4.1 Intervention site (Mandalong): Phase 1, Phase 2 and Phase 3

General profile of the participants

At the Intervention site (Mandalong), 259, 236, and 239 participants completed Phase 1, Phase 2 and Phase 3 surveys respectively. A total of 102 participants completed Phase 1 and 2 surveys, 83 participants completed Phase 2 and 3 surveys, and 60 participants completed all 3 surveys. The average age was similar at all surveys, with an average age of participants at 43.5 (SD 10.8) years at Phase 1, 43.1 (SD 10.7) years at Phase 2 and 43.5 (SD 10.4) at Phase 3.

At each survey, the current role of the majority of participants were Miners, followed by Deputy, Fitter and Electrician. The distribution of current roles was similar at each survey time-point (Table 2).

Table 2 – Distribution of participants by current role at the Intervention site (Mandalong) at each Phase

Current role	Phase 1	Phase 2	Phase 3
Electrician	28	23	29
Fitter	37	31	28
Deputy	34	39	32
Miner	137	132	143
Other	21	11	7

Participants were fairly evenly distributed across the five different shifts at each survey phase, and number in each shift was similar across each survey phase (Table 3). Thus, there is an even representation of participants by shift.

Table 3 – Distribution of participants by shift at the Intervention site (Mandalong) at each Phase

Shift	Phase 1	Phase 2	Phase 3
Afternoon	53	46	44
Day	52	55	48
Night	53	52	49
Weekend Day	47	37	45
Weekend Night	52	45	53

In terms of work location, more than two-thirds of participants were employed at the Development location at all three survey phases. The distribution of participants by location of work at Phase 1, 2 and 3 were similar (Table 4).

Table 4 – Distribution of participants by location of work at the Intervention site (Mandalong) at each Phase

Location of work	Phase 1	Phase 2	Phase 3
Development	151	150	165
Longwall	35	34	34
Development and Longwall	30	23	25
Other	30	17	10

Psychological distress

Psychological distress was measured by participant K10 scores. Figure 1 provides an overview of the scores showing the percentage of participants reporting low, moderate, high and very high levels of psychological distress at each survey Phase. Figure 1 also shows comparisons with the levels of psychological distress observed in those who are currently employed at other mines (27), and currently employed Australians (28). The percentage of Intervention site (Mandalong) participants who reported moderate, high and very high levels of psychological distress was 36.4% at Phase 1, 38.7% at Phase 2 and 38.6% at Phase 3. At all phases, this data is closely aligned with data from other mine samples (39.1%) (27). However at all phases, the percentage is noticeably higher than currently employed Australians (26.2%) (28). The numbers of participants reporting low levels of distress remained fairly constant, however in Phase 2 there were more participants reporting high levels of distress than Phase 3, and in Phase 3 there were more participants reporting moderate levels of distress than in Phase 2. There was a slight increase in those participants reporting very high levels of distress over the three phases.

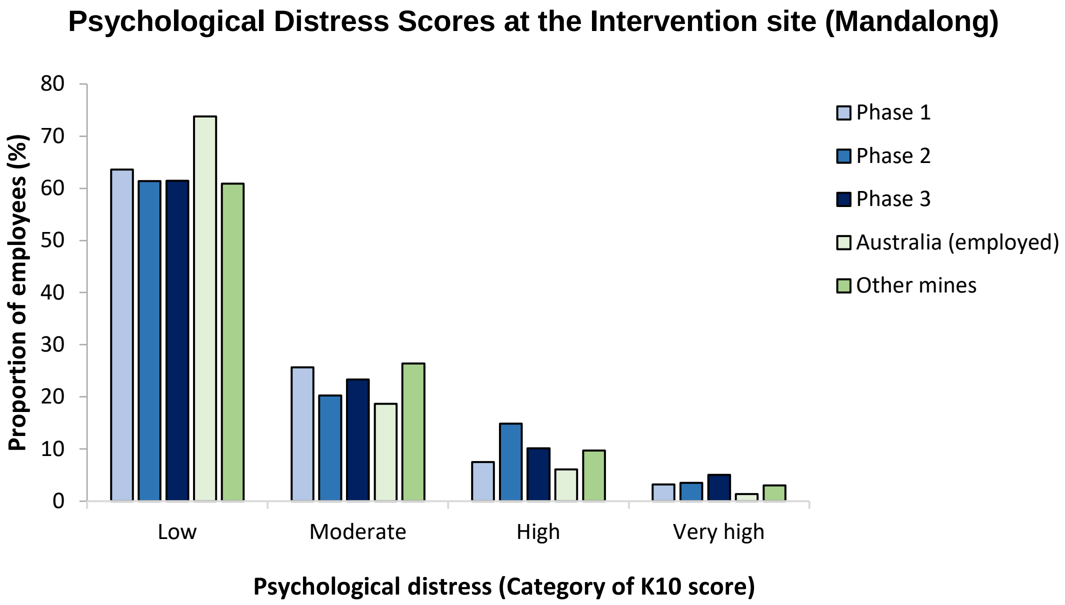

Figure 1 – Comparison of proportion of participants in each psychological distress (K10) category at the Intervention site (Mandalong) between each Phase, employed Australians, and employees at other mine sites

The percentage of participants in the different categories of psychological distress at Phase 1, Phase 2 and Phase 3 is shown in Table 5. The percentage difference between Phase 1 and Phase 3 (the beginning and end of the task rotation intervention) can also be seen in Table 5. For each psychological distress category, there was no significant change in the proportion of participants in that category between the beginning and the end of the task rotation intervention.

Table 5 – Distribution of participants by psychological distress (K10) category at the Intervention site (Mandalong) at each Phase

Categories	Phase 1 (%) n = 257	Phase 2 (%) n = 236	Phase 3 (%) n = 239	Difference between Phase 1 and Phase 3
Low	63.6	61.4	61.4	2.2
Moderate	25.7	20.3	23.3	2.4
High	7.5	14.9	10.2	-2.7
Very High	3.2	3.5	5.1	-1.9

Fatigue

Fatigue scores were calculated from the 'Need for Recovery after Work' scale results (Table 6). There was an increase in fatigue scores between Phase 1, Phase 2 and Phase 3 with significantly higher reported fatigue levels at Phase 3, compared to Phase 1. The mean fatigue score at all time points were less than that of the normal population (>54).

Table 6 – Average fatigue score of participants at the Intervention site (Mandalong) at each Phase

Fatigue Score	Phase 1	Phase 2	Phase 3	Difference between Phase 1 and Phase 3	Population norm
Average (Confidence Interval)	38.1 (35.0 – 41.1)	40.4 (37.2 – 43.6)	42.7 (39.4 – 46.1)	4.6	>54

Quality of Life

Figure 2 illustrates mean QOL scores for Intervention site (Mandalong) participants at Phase 1, Phase 2 and Phase 3 across four QOL domains: physical, psychological, social, and environmental. Higher scores indicate higher QOL. This data is also compared with data from Australian norms (22). Mean QOL scores for all Intervention site (Mandalong) participants in the physical and environmental domains reduced over the 12 month period. The mean QOL score reduced in the social domain between Phase 1 and 2, however remained constant between Phase 2 and 3. The mean QOL score in the psychological domain remained constant between Phase 2 and Phase 3, and improved between Phase 1 and 2. In all four domains the scores at the Intervention site (Mandalong) were lower than that of Australian norms at all survey phases, except the social domain at Phase 1. Significant differences were found between Phase 1 and Phase 3 in the physical, psychological and environmental domains.

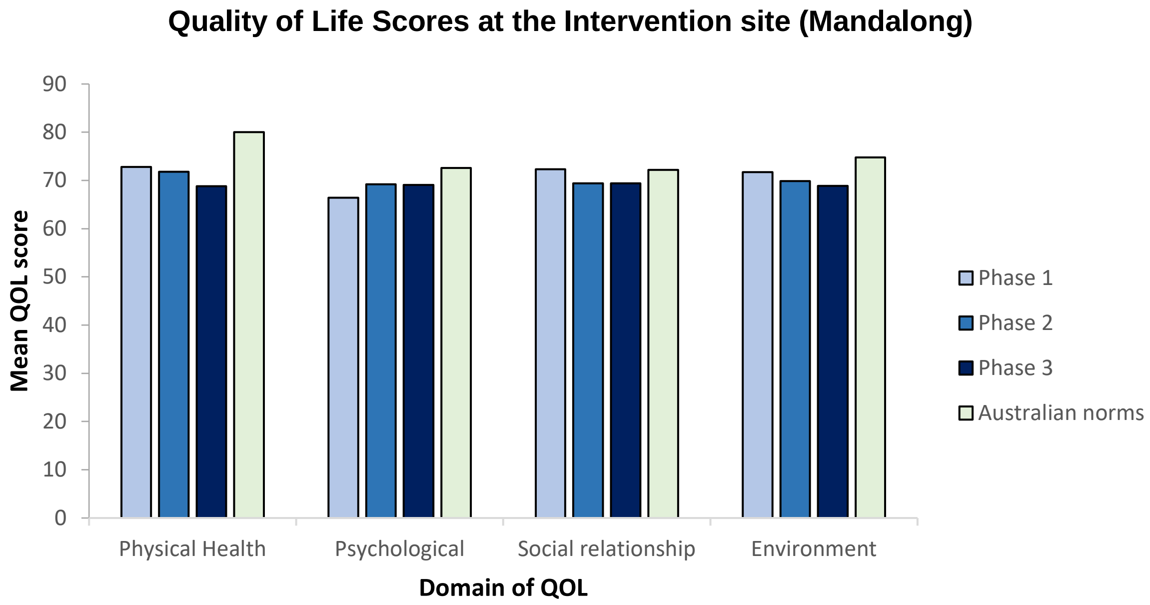

Figure 2 – Comparison of mean QOL score at the Intervention site (Mandalong) between each Phase and Australian norms, grouped by the four domains of QOL (Physical Health, Psychological, Social relationship and Environment)

Summary statistics of the four QOL domains are presented in Table 7. When considering differences between Phase 1 and Phase 3 there were significant differences in the physical health domain and environment domain (downward), and a significant improvement in the psychological domain.

Table 7 – Summary statistics of QOL scores by domain at the Intervention site (Mandalong) at each Phase with Australian norms for comparison, and difference between Phase 1 and Phase 3

Domain	Phase 1	Phase 2	Phase 3	Australian norms	Difference between Phase 1 and Phase 3
Physical Health	72.8	71.8	68.8	80.0	-4.0**
Psychological	66.4	69.2	69.1	72.6	2.7*
Social relationship	72.3	69.4	69.4	72.2	-2.9
Environment	71.7	69.9	68.9	74.8	-2.8*

*indicates significant at *p* <0.05 & **indicates significant at *p* <0.001

Musculoskeletal Discomfort

Descriptive analysis of the Nordic Musculoskeletal Questionnaire identified the lower back, knee and neck as the regions of the body with the highest rates of reported musculoskeletal discomfort experienced at any time *or* during the past 12 months at the Intervention site

(Mandalong). As shown in Figure 3, those reporting having musculoskeletal discomfort ‘in the last 12 months’ was reduced across all body regions, with the exception of the neck where there was a slight increase between Phase 1 and Phase 3. In addition, there was a significant reduction in the proportion of participants reporting having ‘ever had any discomfort’ between Phase 1 and Phase 3 in both the left shoulder and the ankle/foot (data not shown).

Musculoskeletal discomfort ‘in the last 12 months’ at the Intervention site (Mandalong)

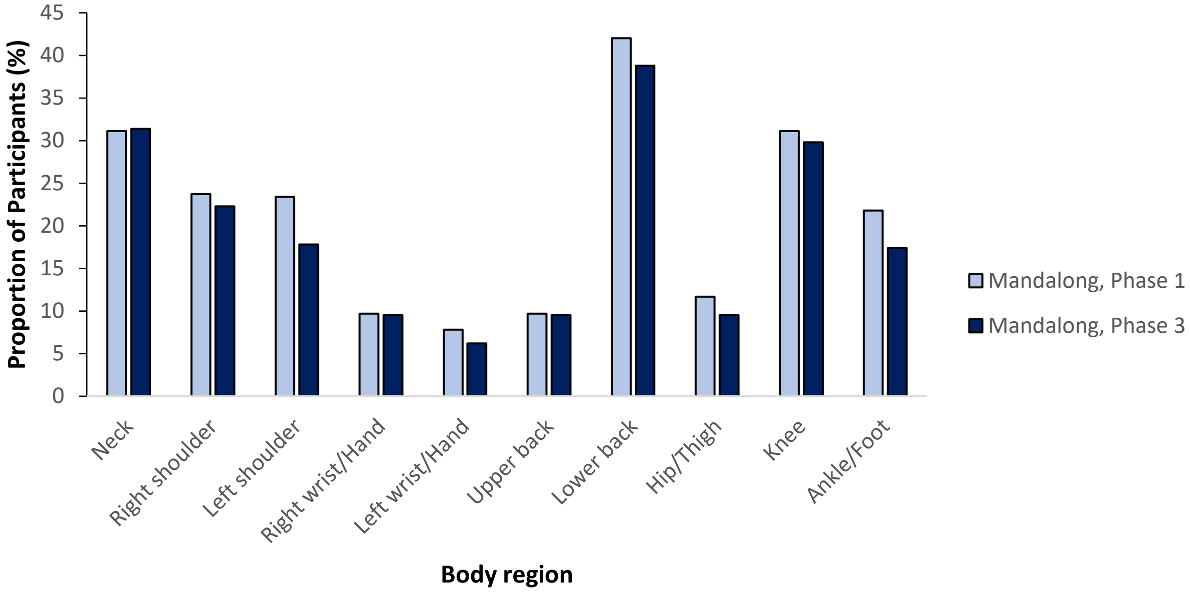

Figure 3 – Comparison by body region of the proportion of participants who ‘had discomfort in the last 12 months’ at the Intervention site (Mandalong) between Phase 1 and Phase 3

Table 8 shows results of those reporting having ‘ever had any discomfort’ across all body regions at both Phase 1 and Phase 3, stratified by location of work. There was no significant difference in musculoskeletal discomfort in any body region by location of work at either Phase.

Table 8 – Comparison of percentage of participants who had ‘ever had any discomfort’ across different body regions, between Development and Longwall and Other locations at Phase 1 and Phase 3, at the Intervention site (Mandalong)

Body region	Phase 1 (n = 257)				Phase 3 (n = 239)			
	Development (n = 151)	Longwall (n = 35)	Other (n = 71)	*p*-value	Development (n = 165)	Longwall (n = 34)	Other (n = 34)	*p*-value
Neck	40.4	40.0	52.1	0.23	40.6	32.4	47.1	0.46
Right shoulder	33.1	40.0	40.9	0.47	29.7	26.5	38.2	0.53
Left shoulder	33.1	34.3	36.6	0.88	24.2	23.5	38.2	0.22
Right wrist/Hand	17.9	5.7	21.1	0.13	17.0	5.9	17.7	0.25
Left wrist/Hand	10.6	5.7	12.7	0.55	11.5	5.9	14.7	0.49
Upper back	13.2	17.1	12.7	0.80	10.9	11.8	17.7	0.55
Lower back	49.1	45.7	64.8	0.06	40.0	52.9	55.9	0.28
Hip/Thigh	16.6	17.1	12.7	0.73	10.9	14.7	14.7	0.72
Knee	40.4	51.4	40.9	0.47	36.8	32.4	55.9	0.08
Ankle/Foot	28.8	28.6	33.8	0.71	20.6	11.7	32.0	0.11

Table 9 shows results of those reporting that they ‘had discomfort in the last 12 months’ across all body regions at both Phase 1 and Phase 3, stratified by location of work. At Phase 1, there was a significant difference in those reporting musculoskeletal discomfort in the lower back in the last 12 months by working location, with those in Development reporting less low back discomfort than those working in the Longwall location, who reported lower levels of discomfort than those in Other locations. At Phase 3, there was a significant difference in those reporting discomfort in the knee in the last 12 months by location. Those working in an Other location had significantly higher discomfort in the knee than those in Development or Longwall locations. Those in the Longwall location reported the least discomfort in the knee across this time period.

Table 9 – Comparison of percentage of participants who 'had discomfort in the last 12 months' across different body regions, between Development and Longwall and Other locations at Phase 1 and Phase 3, at the Intervention site (Mandalong)

Body region	Phase 1 (n = 257)				Phase 3 (n = 239)			
	Development (n = 151)	Longwall (n = 35)	Other (n = 71)	*p*-value	Development (n = 165)	Longwall (n = 34)	Other (n = 34)	*p*-value
Neck	26.5	31.4	40.8	0.10	32.1	29.4	32.4	0.95
Right shoulder	25.2	25.7	19.7	0.64	23.0	17.6	29.4	0.52
Left shoulder	25.2	17.1	22.5	0.59	17.0	14.7	29.4	0.20
Right wrist/Hand	9.9	0.0	14.1	0.07	10.9	2.9	11.7	0.34
Left wrist/Hand	8.0	2.9	9.9	0.45	6.1	5.9	8.8	0.83
Upper back	9.9	14.3	7.0	0.49	8.5	8.8	17.5	0.26
Lower back	35.1	40.0	57.8	<0.01*	39.4	32.4	47.1	0.46
Hip/Thigh	11.3	14.3	11.3	0.87	7.9	14.7	11.8	0.41
Knee	32.5	31.4	28.2	0.81	29.1	17.7	47.1	0.03*
Ankle/Foot	19.2	17.1	29.6	0.17	17.0	8.8	29.4	0.08

*indicates significant at $p < 0.05$

The results of participants from each work location reporting 'had discomfort in the last 12 months' was also compared *between* Phase 1 and Phase 3, as shown in Table 10. There was a significant increase in reported discomfort in the knee between Phase 1 and Phase 3 for those working in an Other location at the Intervention site (Mandalong).

Table 10 – Comparison of percentage of participants who 'had discomfort in the last 12 months' across different body regions, between Phase 1 and Phase 3 at the Development, Longwall and Other locations at the Intervention site (Mandalong)

Body region	Development			Longwall			Other		
	Phase 1 (n = 151)	Phase 3 (n = 165)	*p*-value	Phase 1 (n = 35)	Phase 3 (n = 34)	*p*-value	Phase 1 (n = 71)	Phase 3 (n = 34)	*p*-value
Neck	26.5	32.1	0.28	31.4	29.4	0.85	40.8	32.4	0.43
Right shoulder	25.2	23.0	0.67	25.7	17.6	0.41	19.7	29.4	0.27
Left shoulder	25.2	17.0	0.08	17.1	14.7	0.79	22.5	29.4	0.41
Right wrist/Hand	9.9	10.9	0.77	0.0	2.9	0.31	14.1	11.7	0.75
Left wrist/Hand	8.0	6.1	0.49	2.9	5.9	0.55	9.9	8.8	0.87
Upper back	9.9	8.5	0.64	14.3	8.8	0.47	7.0	17.5	0.11
Lower back	35.1	39.4	0.46	40.0	32.4	0.49	57.8	47.1	0.29
Hip/Thigh	11.3	7.9	0.36	14.3	14.7	0.96	11.3	11.8	0.91
Knee	32.5	29.1	0.56	31.4	17.7	0.19	28.2	47.1	0.05*
Ankle/Foot	19.2	17.0	0.64	17.1	8.8	0.26	29.6	29.4	0.98

*indicates significant at $p < 0.05$

Participants at the Intervention site (Mandalong) reported whether the cause of musculoskeletal discomfort was the result of a work-related or non-work related accident (Table 11). Overall there was a reduction in reported discomfort due to both non-work related accidents and work-related accidents between Phase 1 and Phase 3. This reduction in reported musculoskeletal discomfort was significant in the ankle/foot due to a non-work related accident. A comparison of discomfort as a result of work-related accident between Phase 1 and Phase 3 is presented in Figure 4.

Table 11 – Comparison of the percentage distribution across different body regions for those responding 'Yes' for the cause of discomfort owing to work-related or non-work related accidents between Phase 1 and Phase 3 at the Intervention site (Mandalong)

Body region	Non-work related accidents (Sporting/Home activity/others)			Work-related accidents		
	Phase 1	Phase 3	*p*-value	Phase 1	Phase 3	*p*-value
Neck	12.9	9.5	0.23	23	21.9	0.77
Right shoulder	12.5	7.4	0.06	17.5	16.2	0.81
Left shoulder	12.5	7.5	0.06	17.1	13.2	0.23
Right wrist/Hand	5.9	3.3	0.17	9.3	8.7	0.81
Left wrist/Hand	4.8	2.9	0.27	7.0	5.4	0.46
Upper back	3.2	2.9	0.84	8.2	7.0	0.61
Lower back	15.2	10.7	0.14	31.1	25.6	0.17
Hip/Thigh	3.1	2.8	0.84	8.2	5.0	0.15
Knee	9.8	8.3	0.56	30.0	24.4	0.16
Ankle/Foot	13.7	7.4	0.02*	16.3	11.6	0.13

*indicates significant at p <0.05

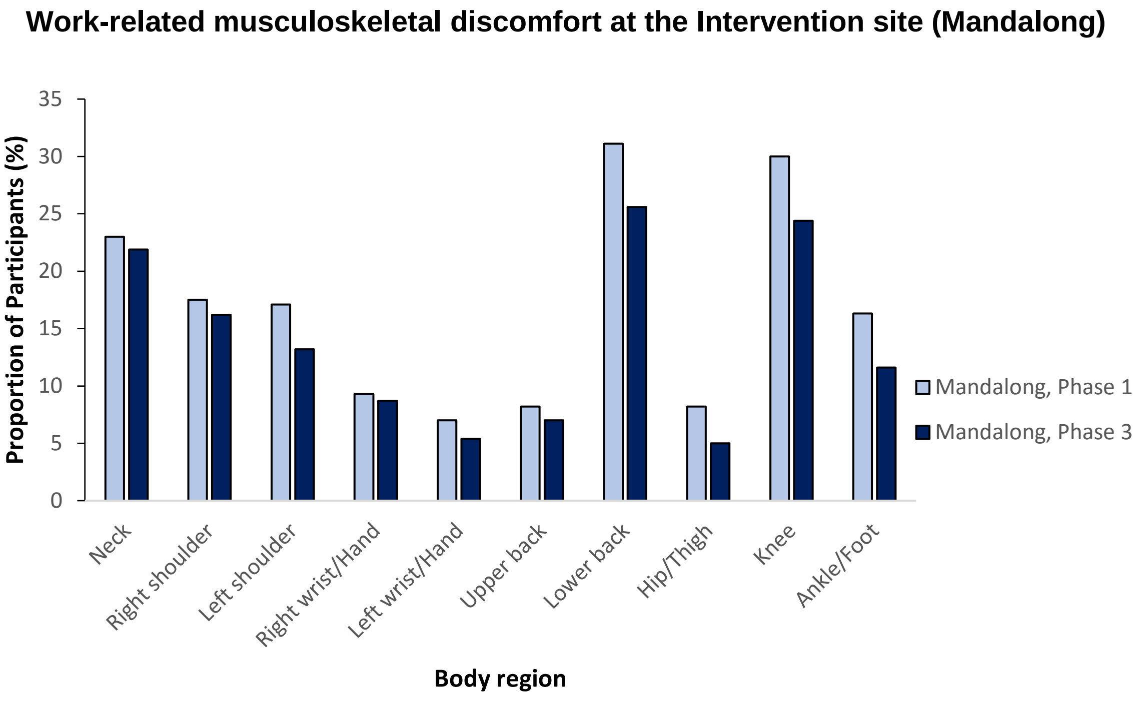

Figure 4 – Comparison of the percentage of participants responding 'Yes' for the cause of discomfort owing to work-related accident across each body region between Phase 1 and Phase 3 at the Intervention site (Mandalong)

Self-reported levels of pain were recorded using a pain score where '0 = no pain' and '10 = the worst pain ever' in each of the body regions. This was calculated for whole of body pain for each participant and transformed to a score out of 100, with lower scores indicating less pain and higher scores indicating more pain. The distribution of categorised pain scores is reported in Table 12. There were significantly more participants reporting no pain, and significantly less reporting one of the higher levels of pain (scores 20 – 30) between Phase 1 and Phase 3.

Table 12 – Comparison of the distribution of total self-reported pain scores between Phase 1 and Phase 3 at the Intervention site (Mandalong)

Pain Score	Phase 1 (n = 257)	Phase 3 (n = 239)	Difference
0	10.9	21.3	-10.4*
>0 and ≤10	38.1	33.5	4.6
>10 and ≤20	24.5	23.0	1.5
>20 and ≤30	17.1	10.9	6.2*
>30 and ≤40	5.5	6.7	-1.2
>40	3.9	4.6	-0.7

*indicates significant at p <0.05

Injury

Incidence of work-place injuries reported to the Intervention mine (Mandalong) were provided by Coal Services, with injuries in the 12 months prior to the task rotation intervention (May 2015 – April 2016) being compared to injuries reported to the mine during the task rotation period (May 2016 – April 2017). As shown in Table 13, there was no significant difference between reported incidence of injury from pre-task rotation to the task rotation period at the Intervention site (Mandalong). Reported discomfort (from the Nordic Musculoskeletal questionnaire) during the task rotation period was much higher than reported injury (Table 13 and Figure 5).

Table 13 – Comparison of the distribution of injury by body region between May 2015 to April 2016 (pre-task rotation) and May 2016 to April 2017 (during task rotation) along with reported discomfort during the task rotation period at the Intervention site (Mandalong)

Type of injury	Injury Pre-Task Rotation	Injury During Task Rotation	Reported Discomfort During Task Rotation
Head/Neck	5	10	76
Back	13	10	94
Shoulder	8	9	65
Knee	8	12	71
Ankle	8	5	42
Other	15	20	54
Total	57	66	402

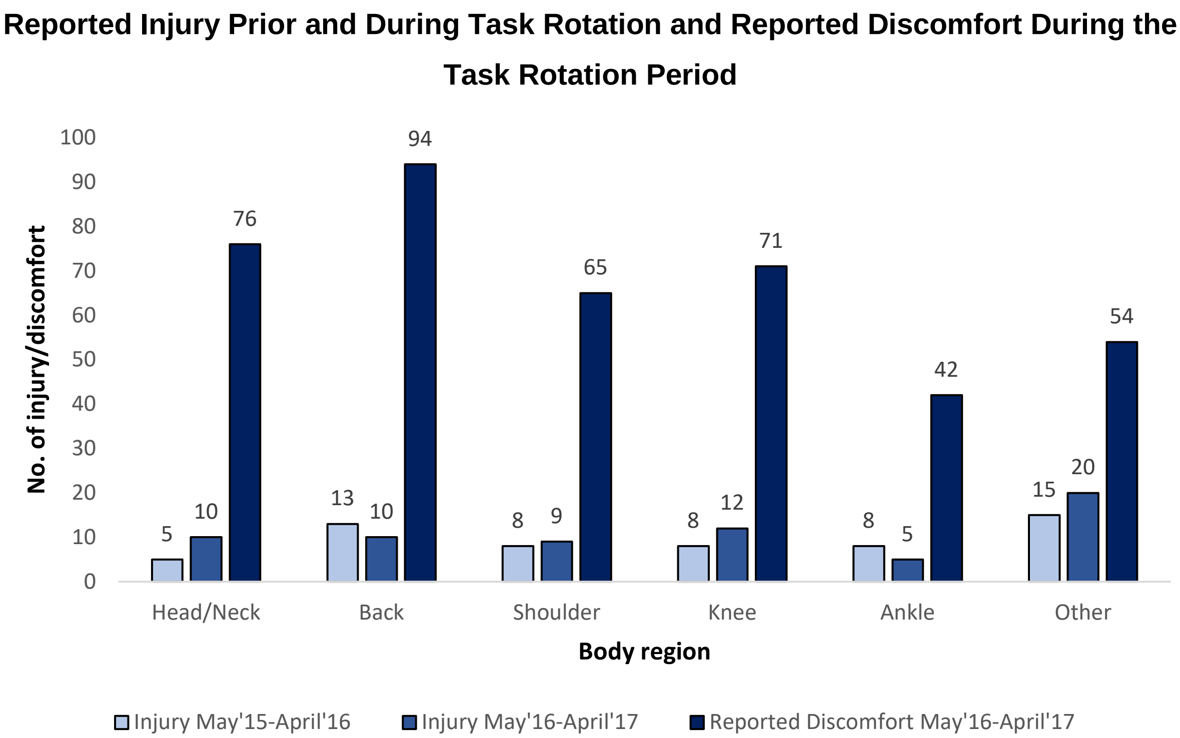

Figure 5 – Frequency and distribution of number injuries by body region between May 2015 to April 2016 (pre-task rotation) and May 2016 to April 2017 (during task rotation) along with reported discomfort during the task rotation period at the Intervention site (Mandalong)

The cause of injury was compared between the two time periods (Figure 6). Prior to the implementation of the task rotation intervention, the majority of injuries were as a result of falls, trips or slips followed by overexertion. During the task rotation period, there were more overexertion injuries and more injuries from being hit by moving objects, but less injuries from slips, trips and falls. Vehicle accidents and hitting objects with part of a body were the least frequent causes of injury during both time periods.

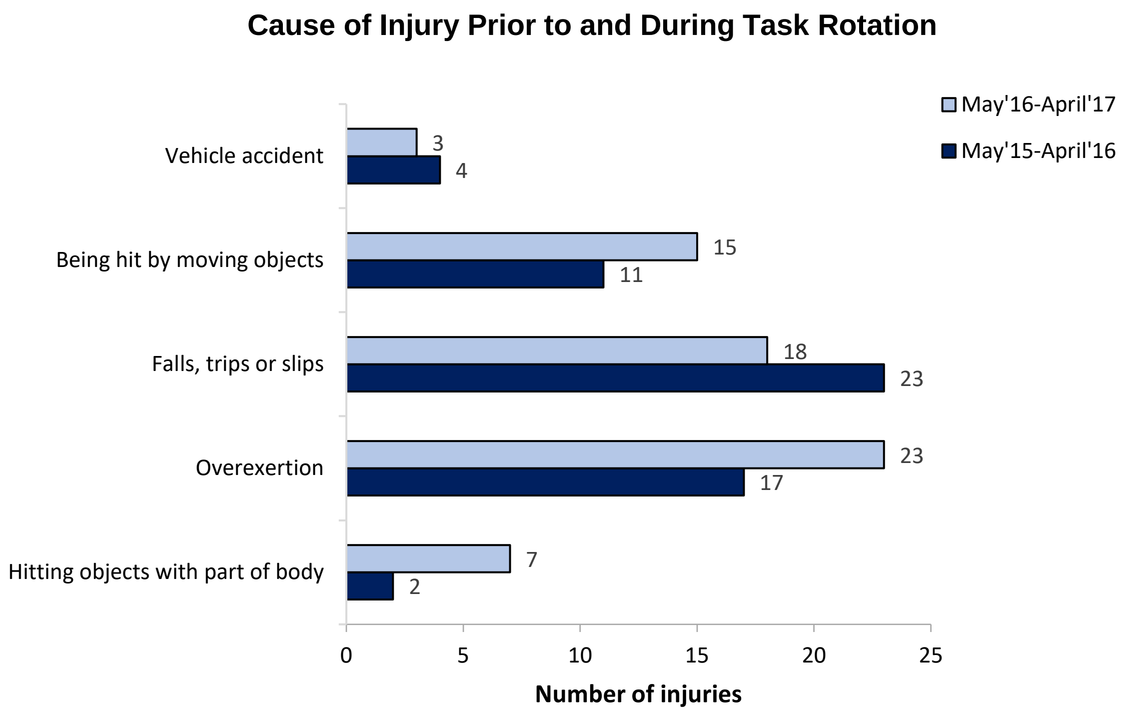

Figure 6 – Frequency and distribution of cause of injury between May 2015 to April 2016 (pre-task rotation) and May 2016 to April 2017 (during task rotation) at the Intervention site (Mandalong)

The nature of each injury was also reported (Figure 7). Most injuries resulted in sprains or strains during both time periods. Fracture was the least common resulting injury. Injury data was also analysed by shift (day, afternoon or night), however no effect was seen on frequency of reported injury- either by pre- or during task rotation or location of injury (data not shown).

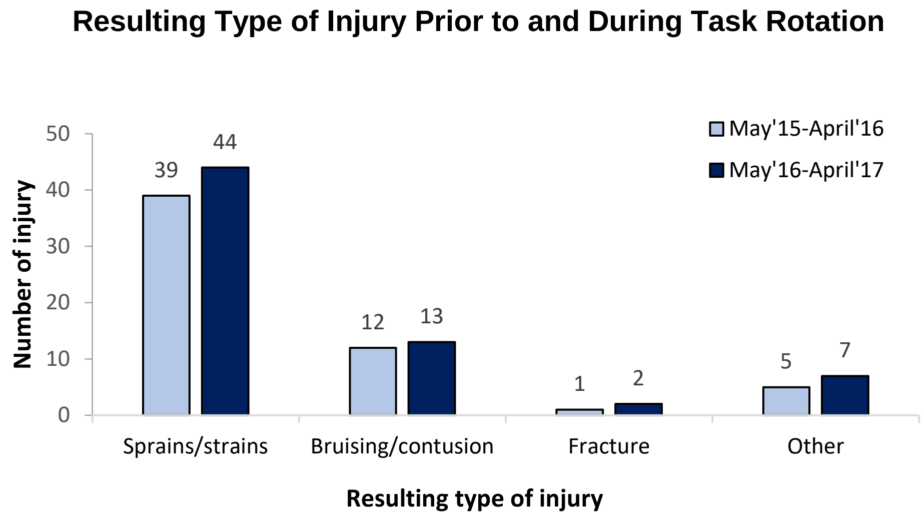

Figure 7 – Frequency and distribution of resulting type of injury between May 2015 to April 2016 (pre-task rotation) and May 2016 to April 2017 (during task rotation) at the Intervention site (Mandalong)

Job Content Questionnaire (JCQ)

The main components of the job strain model (29) were included in the survey with questions related to skill discretion, decision authority and psychological job demands and support.

Table 14 provides the results of the JCQ for the Intervention site (Mandalong) at Phase 1, Phase 2 and Phase 3. A higher number of participants indicated they had very low skill discretion and slightly less had high levels of skill discretion when comparing Phase 1 and Phase 3, however this was not significantly different. Similarly there were some changes in decision authority with less reporting high levels of decision authority, however this was not significantly different. There was however a significant difference in very low levels of reported psychological job demands between Phase 1 and Phase 3.

Table 14 – Comparison of JCQ scores across the four categories between each Phase at the Intervention site (Mandalong)

Category	Phase 1 (%)	Phase 2 (%)	Phase 3 (%)	Difference between Phase 1 and Phase 3
Skill discretion				
Very low	7.0	9.3	10.2	3.2
Low	57.6	59.8	58.5	0.9
Moderate	32.3	28.8	29.7	-2.6
High	3.1	2.1	1.7	-1.4
Decision Authority				
Very low	12.1	16.1	13.6	1.5
Low	23.0	24.2	27.5	4.5
Moderate	42.4	38.1	41.5	-0.9
High	22.6	21.6	17.4	-5.2
Psychological job demand				
Very low	17.1	14.4	10.2	-6.9*
Low	61.1	64.0	67.0	5.9
Moderate	17.9	17.4	16.1	-1.8
High	3.9	4.2	6.8	2.9

*****indicates significant at p <0.05

Weekly schedule of task rotation

Weekly task rotation schedules were collected for each of the Development and Longwall crews for each of the shifts for the 52 weeks of the task rotation intervention. Table 15 identifies the number of days of data collected across each shift and the number of days included in analysis after removal of days of no or limited production, scheduled public holidays and any missing days.

Table 15 – Distribution of number of day's data available and included in the analysis by shift and Development or Longwall location

Shift	Development		Longwall	
	No. of days data available	No. of days Included in the analysis	Total days data available	No. of days Included in the analysis
Afternoon shift	209	186	183	140
Day shift	208	94	204	67
Night shift	172	163	208	140
Weekend day shift	129	124	117	79
Weekend night shift	147	128	114	84

When looking at the tasks completed over each shift, the following table outlines the number of shifts where one person did the same task all shift (one rotation), two people did the one task (two rotation) or three people did the one task (three rotations) over the course of the shift. Table 16 shows the number of days that one, two or three rotations for any one task were completed for each shift in each work location over the 12 month period.

Table 16 – Number of days by shift and segment rotation in Development and Longwall location

Shift	One rotation days		Two rotation days		Three rotation days	
	Development	Longwall	Development	Longwall	Development	Longwall
Afternoon shift	1	6	43	117	142	17
Day shift	5	2	66	32	23	33
Night shift	4	-	20	133	139	7
Weekend day shift	0	-	2	12	122	67
Weekend night shift	3	1	8	12	117	71

Location of work: Development

At the Development location, the number of rotations per task is shown in Table 17. The information conveys the number of participants who rotated through each specific task per shift. Table 17 shows the number of times that one, two or three different participants completed the task in any one shift along with the percentage. In Development as a collective (all shifts), the Right Hand (RH) bolter was most commonly completed by three different individuals at 62.8% of the time. The Left Hand (LH) bolter, Miner, and Shuttle Car (SC) operator respectively were the next tasks most commonly being rotated three times per shift. In contrast, the LH offsider and Supplies were more commonly being rotated twice per shift.

Table 17– Number of rotations performed by task in Development location of work at the Intervention site (Mandalong)

Task Name	Single shift segment rotations (%)	Two shift segment rotations (%)	Three shift segment rotations (%)	Total (%)
Miner	39 (5.6)	246 (35.4)	410 (59.1)	694 (100)
LH bolter	22 (3.20)	235 (33.9)	433 (62.5)	693 (100)
LH offsider	107 (26.2)	228 (55.7)	74 (18.1)	409 (100)
RH bolter	44 (6.5)	207 (30.7)	423 (62.8)	674 (100)
SC operator	64 (9.2)	226 (32.6)	403 (58.2)	693 (100)
Supplies	110 (16.8)	351 (53.7)	193 (29.5)	654 (100)

When considering the mean number of task rotations per participant for those that work at the Development location, most participants on afternoon shift, day shift, night shift and weekend night shift completed two task rotations on average, whereas most participants on weekend day shift were able to complete on average three task rotations (Table 18). However, the range of days that participants completed one, two or three rotations is very wide. For example, on afternoon shift during the study period, the average number of days participants were able to complete two rotations of tasks was 38 within the range between 1 and 111 days of actually doing two tasks during the shift. Those participants who worked less than 10% of the time in any shift were excluded from the analysis.

Table 18 – Average number of days worked per participant and number of different task rotations in the Development location of work at the Intervention site (Mandalong)

Shift	No. of days	No. of Participants	Single task Mean (SD) & Range	Two task Mean (SD) & Range	Three task Mean (SD) & Range
Afternoon shift	185	37	26 (20.2) 3–70	38 (28.1) 1–111	5 (12.4) 0–46
Day shift	94	28	15 (8.0) 2–35	22 (11.5) 1–44	3 (4.6) 0–23
Night shift	163	33	23 (14.1) 1–58	31 (24.1) 0–66	7 (10.5) 0–42
Weekend day shift	124	30	10 (12.9) 0–56	14 (10.4) 1–40	20 (14.5) 0–50
Weekend night shift	128	38	15 (11.8) 1–59	19 (11.1) 0–39	5 (4.8) 0–18

Location of work: Longwall

Table 19 provides information on the tasks and number of rotations per shift for participants working at the Longwall location. The information conveys the number of participants who rotated through each specific task per shift. Table 19 shows the number of times that one, two or three different people completed the task in any one shift along with the percentage. The Shearer driver and Boot-end tasks were most commonly completed by three different individuals in a shift, but this was only approximately a quarter of the time (~25%). Tasks were most commonly rotated between two people with the Chock operator most commonly frequently rotated over 70% of the time. Trades were most commonly rotated twice per shift.

Table 19 – Number and percentage of rotations performed by task in the Longwall location at the Intervention site (Mandalong)

Task Name	Single shift segment rotations (%)	Two shift segment rotations (%)	Three shift segment rotations (%)	Total (%)
Shearer Driver	28 (5.5)	357 (70.0)	125 (24.5)	510 (100)
Chock Operator	72 (15.5)	358 (76.8)	36 (7.7)	466 (100)
Chock Operator (2)	97 (24.3)	288 (72.0)	15 (3.8)	400 (100)
Boot-end attendant	37 (7.4)	333 (67.0)	127 (25.6)	497 (100)
Trades	6 (1.5)	336 (83.6)	60 (14.9)	402 (100)

When considering the effect of shift on the mean number of task rotations per miner at the Longwall location, most participants on afternoon shift, day shift and night shift completed only one task during the shift, whereas those working on weekend night shift and weekend day shift completed two task rotations on average, as shown in Table 20.

For example, on afternoon shift the mean number of days that a participant did one rotation was 35, but this varied between 9 and 60 days of doing one task rotation. Those participants who worked less than 10% of the time in any shift were excluded from the analysis.

Table 20 – Average number of days worked per participant and number of different task rotations by shift type at the Longwall location at the Intervention site (Mandalong)

Shift	No. of days	No. of Participants	Single task Mean (SD) & Range	Two task Mean (SD) & Range	Three task Mean (SD) & Range
Afternoon shift	140	11	35(18.9)	24 (26.8)	1 (1.0)
			9–60	0–65	0–2
Day shift	67	13	15 (5.4)	13 (13.2)	0.1 (0.3)
			6–23	0–32	0–1
Night shift	140	10	54 (40.4)	36 (35.2)	1 (0.5)
			4–113	0–104	0–1
Weekend day shift	79	11	9 (7.3)	27 (14.5)	5 (6.8)
			2–25	2–48	0–16
Weekend night shift	84	13	16 (9.8)	21 (16.4)	2 (1.6)
			3–39	0–48	0–4

Comparison: Development and Longwall locations of work

When comparing the Development and Longwall locations, there was a significant difference in the average number days for participants who completed one, two or three task rotations, with significantly more rotations in the Development location. This is shown in Table 21.

Table 21 – Difference in the average number days per participant and number of task rotations between Development (n = 166) and Longwall (n = 58) locations

Task	Development Location (SD)	Longwall Location (SD)	Difference
Single task	52 (32.5)	25 (25.6)	27*
Two tasks	72 (43.5)	25 (22.4)	47*
Three tasks	22 (21.3)	2 (2.5)	20*

*indicates significance at *p* <0.001

4.2 Control site (Springvale): Phase 1, Phase 2 and Phase 3

General profile of the participants

At the Control site (Springvale), 185, 208 and 203 participants completed Phase 1, Phase 2 and Phase 3 surveys respectively. A total of 54 participants completed Phase 1 and Phase 2 surveys; 74 completed Phase 2 and Phase 3, and a total of 35 completed all 3 surveys. The average age of participants was 42.5 years (SD 10.4) at Phase 1, 40.6 years (SD 10.6) at Phase 2; and 42.0 years (SD10.7) at Phase 3.

At each survey, the majority of participants were Miners, followed by Fitter, Electrician and Deputy. The distribution of current roles was similar at each survey time-point (Table 22).

Table 22 – Distribution of participants by current role at the Control site (Springvale) at each Phase

Current role	Phase 1	Phase 2	Phase 3
Electrician	22	24	22
Fitter	27	27	23
Deputy	17	14	18
Miner	97	112	124
Other	20	31	16

There were relatively fewer participants from the weekend shifts, particularly weekend night shift, who completed the survey at all survey time points (Table 23). Overall, the distributions of participants by shift type are similar at all survey time points.

Table 23 – Distribution of participants by shift at the Control site (Springvale) at each Phase

Shift	Phase 1	Phase 2	Phase 3
Afternoon	54	62	57
Day	46	63	63
Night	52	58	49
Weekend Day	17	24	29
Weekend Night	12	1	3

In terms of location of work, more than two-thirds of participants were employed in Development work at all three survey phases. The distribution of participants by location of work at Phase 1, Phase 2 are Phase 3 are very similar (Table 24).

Table 24 – Distribution of participants by location of work at the Control site (Springvale) at each Phase

Location of work	Phase 1	Phase 2	Phase 3
Development	90	103	125
Longwall	31	35	40
Development & Longwall	9	9	6
Other	29	33	20

Psychological distress

Psychological distress was measured by participant K10 scores. Figure 8 provides an overview of the scores showing the percentage of participants reporting low, moderate, high and very high levels of psychological distress at each survey phase. Figure 8 also shows comparisons with the levels of psychological distress observed in those who are currently employed at other mines (27), and currently employed Australians (28). The percentage of Control site (Springvale) participants who reported moderate, high and very high levels of psychological distress was 40.7% at Phase 1, 44.5% at Phase 2 and 32.8% at Phase 3. This data is closely aligned at Phase1, slightly higher at Phase 2 and lower at Phase 3 when compared to data from other mine samples (39.1%) (27). However at all phases the percentage is noticeably higher than currently employed Australians (26.2%) (28). There is a corresponding decrease in the numbers of participants reporting moderate, high or very high levels of distress between Phases 1, 2 and 3 with an increase in those reporting low levels of distress.

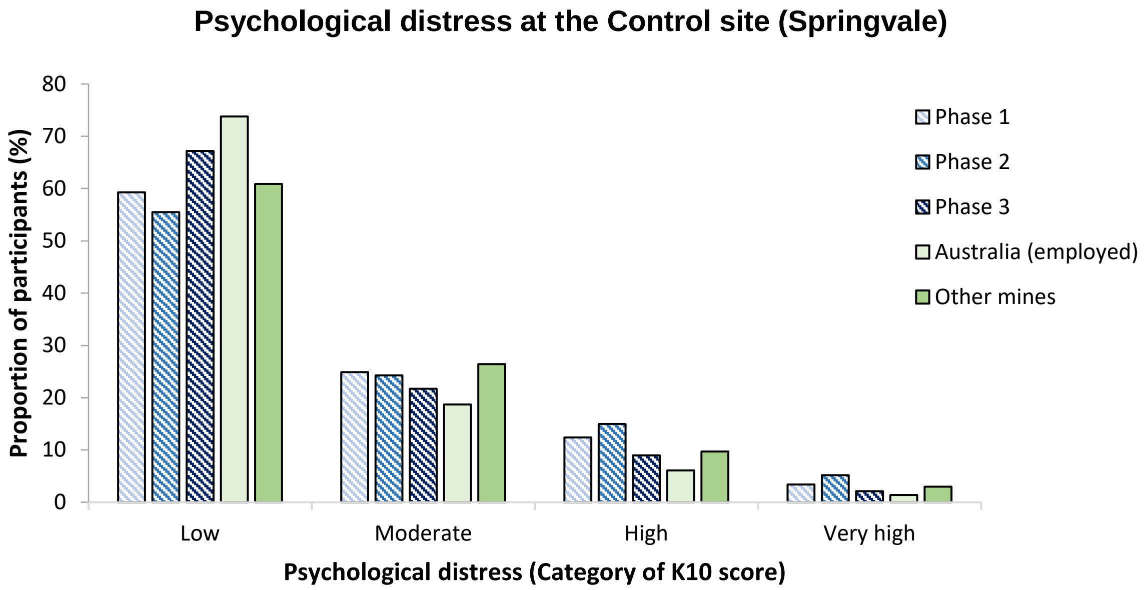

Figure 8 – Comparison of proportion of participants in each psychological distress (K10) category at the Control site (Springvale) between each Phase, employed Australians, and employees at other mine sites

The percentage of participants in the different categories of psychological distress at Phase 1, Phase 2 and Phase 3 is shown in Table 25. For each psychological distress category, there was no significant change in the proportion of participants reporting levels in that category between Phase 1 and Phase 3.

Table 25 – Distribution of participants by psychological distress category (K10) at the Control site (Springvale) at each Phase

Categories	Phase 1 (%) n = 175	Phase 2 (%) n = 206	Phase 3 (%) n = 189	Difference between Phase 1 and Phase 3
Low	59.3	55.5	67.2	-7.9
Moderate	24.9	24.3	21.7	3.6
High	12.4	15.0	9.0	3.4
Very High	3.4	5.2	2.1	-0.2

Fatigue

Fatigue scores were calculated from the 'Need for Recovery after Work' scale results (Table 26). There was a significant decrease in fatigue scores between Phase 1 and Phase 2; however, the score then increased in Phase 3, but remained at a lower level than at Phase 1. The mean fatigue score at all time points were less than that of the normal population (>54).

Table 26 – Average fatigue score of participants at the Control site (Springvale) at each Phase

Fatigue Score	Phase 1	Phase 2	Phase 3	Difference between Phase 1 and Phase 3	Population norm
Average (Confidence Interval)	44.5 (40.9 - 48.1)	33.4 (29.9 – 36.9)	38.0 (34.7 – 41.2)	6.5*	>54

* indicates significant at p <0.01

Quality of Life

Figure 9 illustrates mean QOL score for Control site (Springvale) participants at Phase 1, Phase 2 and Phase 3 across the four QOL domains: physical, psychological, social, and environmental. Higher scores indicate higher QOL. This data is also compared with data from Australian norms (22). Mean QOL scores for all Control site (Springvale) participants in the environmental domain reduced over the 12 month period. The mean QOL score reduced in the social domain between Phase 1 and 2, however improved between Phase 2 and 3. The mean QOL score in the psychological domain improved between Phase 1 and 2 and then remained constant between Phase 2 and Phase 3. In all four domains, the scores at the Control site (Springvale) were lower than that of Australian norms at all survey phases, except the social domain at Phase 1 and Phase 3.

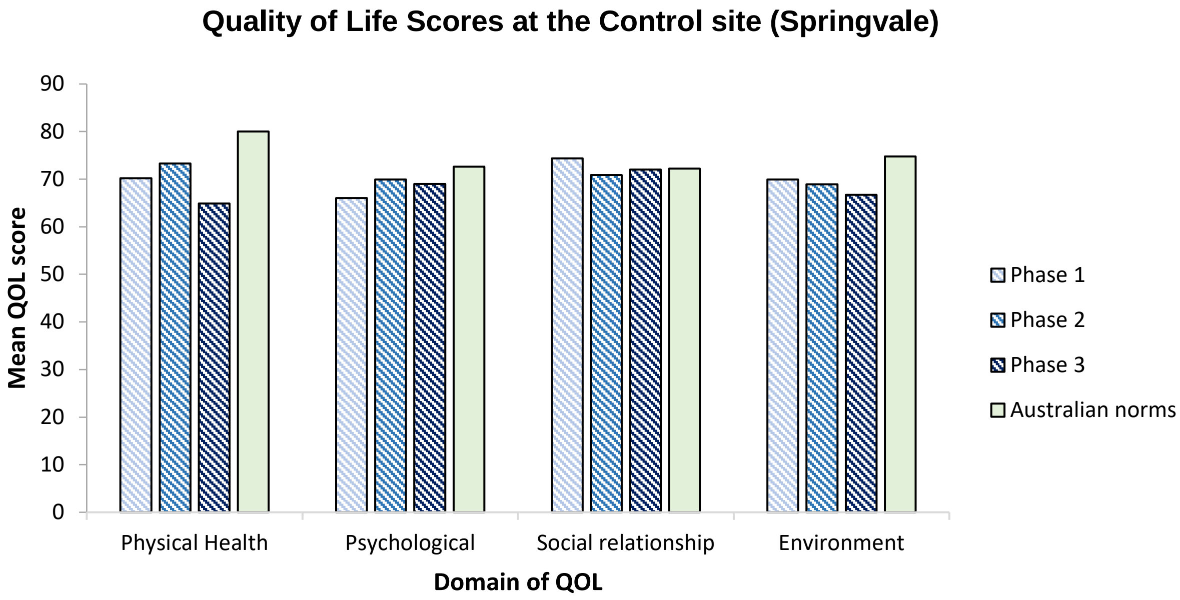

Figure 9 – Comparison of mean QOL score at the Control site (Springvale) between each Phase and Australian norms, grouped by the four domains of QOL (Physical Health, Psychological, Social relationship and Environment)

Summary statistics of the four QOL domains are presented in Table 27. When considering differences between Phase 1 and Phase 3, there were significant differences in the physical health domain and environment domain (downward) and a significant improvement in the psychological domain.

Table 27 – Summary statistics of QOL scores by domain at the Control site (Springvale) at each Phase with Australian norms for comparison, and difference between Phase 1 and Phase 3

Domain	Phase 1	Phase 2	Phase 3	Australian norms	Difference between Phase 1 and Phase 3
Physical Health	70.2	73.3	64.9	80.0	-5.3**
Psychological	66.0	69.9	69.0	72.6	3*
Social relationship	74.4	70.9	72.0	72.2	-2.4
Environment	69.9	68.9	66.7	74.8	-3.2**

* indicates significant at *p* <0.05 & ** indicates significant at *p* <0.01

Musculoskeletal Discomfort

Descriptive analysis of the Nordic Musculoskeletal Questionnaire identified the lower back, knee and neck as the regions of the body with the highest rates of reported musculoskeletal discomfort at any time *or* during the past 12 months at the Control site (Springvale). There was a significant reduction in the percentage of participants reporting 'ever had any discomfort' between Phase 1 and Phase 3 in the neck, right shoulder and lower back (data not shown).

As shown in Figure 10, musculoskeletal discomfort 'in the last 12 months' reduced across all body regions, with the exception of the ankle/foot, between Phase 1 and Phase 3. This reduction was significant in the right shoulder (p <0.05).

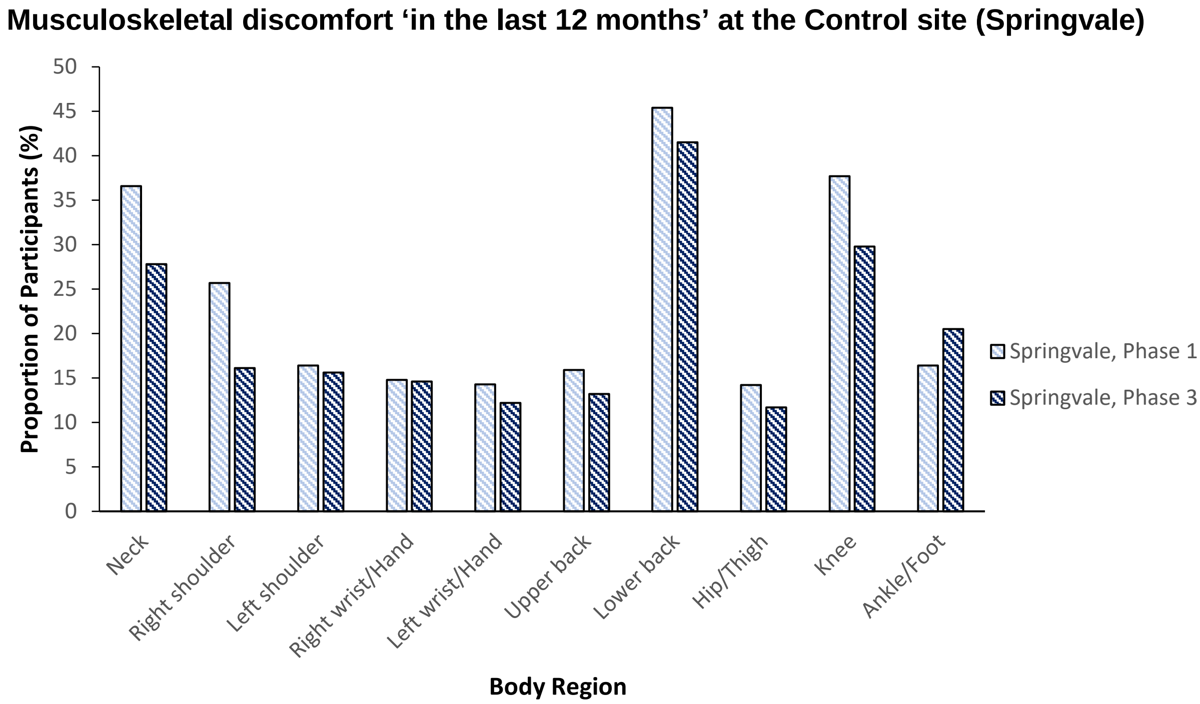

Figure 10 – Comparison by body region of the proportion of participants 'had discomfort in the last 12 months' at the Control site (Springvale) between Phase 1 and Phase 3

Table 28 shows results of those reporting that they 'ever had any discomfort' across all body regions at both Phase 1 and Phase 3, stratified by location of work. There was no significant difference in musculoskeletal discomfort in any body region by location of work at either Phase.

Table 28 – Comparison of percentage of participants who had 'ever had had any discomfort' across different body regions, between Development and Longwall and Other locations at Phase 1 and Phase 3, at the Control site (Springvale)

Body region	Phase 1 (n = 183)				Phase 3 (n = 203)			
	Development (n = 90)	Longwall (n = 31)	Other (n = 62)	*p*-value	Development (n = 125)	Longwall (n = 40)	Other (n = 26)	*p*-value
Neck	50.0	48.4	53.2	0.89	36.0	37.5	50.0	0.41
Right shoulder	37.8	32.3	35.5	0.85	22.4	17.5	23.1	0.79
Left shoulder	26.7	32.3	21.0	0.48	22.4	22.5	23.1	0.99
Right wrist/Hand	20.0	25.8	22.6	0.78	18.4	22.5	19.2	0.85
Left wrist/Hand	15.6	16.1	25.8	0.26	15.2	17.5	15.4	0.94
Upper back	16.8	22.6	21.0	0.70	14.4	20.0	19.2	0.63
Lower back	70.0	58.1	56.5	0.19	48.0	50.0	69.2	0.14
Hip/Thigh	17.8	29.0	22.6	0.40	11.2	25.5	15.5	0.10
Knee	45.6	48.4	48.4	0.93	37.6	42.5	50.0	0.48
Ankle/Foot	26.7	25.8	25.8	0.99	24.4	27.5	30.7	0.80

Table 29 shows results of those reporting that they 'had discomfort in the last 12 months' across all body regions at both Phase 1 and Phase 3, stratified by location of work. There was no significant difference in musculoskeletal discomfort in any body region by location of work at either Phase.

Table 29 – Comparison of percentage of participants who 'had discomfort in the last 12 months' across different body regions, between Development and Longwall and Other locations at Phase 1 and Phase 3, at the Control site (Springvale)

Body region	Phase 1 (n = 183)				Phase 3 (n = 203)			
	Development (n = 90)	Longwall (n = 31)	Other (n = 62)	*p*-value	Development (n = 125)	Longwall (n = 40)	Other (n = 26)	*p*-value
Neck	34.4	41.9	37.1	0.75	24.0	30.0	38.5	0.29
Right shoulder	25.6	25.8	25.8	1.00	18.4	5.0	22.1	0.08
Left shoulder	18.9	22.6	9.7	0.19	14.4	12.5	23.1	0.46
Right wrist/Hand	11.1	19.5	17.7	0.38	12.8	15.0	19.2	0.68
Left wrist/Hand	10.0	12.9	21.0	0.16	10.4	12.5	15.4	0.75
Upper back	14.4	19.3	16.1	0.81	12.0	15.1	15.4	0.83
Lower back	52.2	41.9	37.1	0.17	37.6	37.5	61.5	0.07
Hip/Thigh	11.1	25.8	12.9	0.12	9.6	17.5	11.5	0.40
Knee	41.1	32.3	35.5	0.62	24.8	32.5	38.5	0.30
Ankle/Foot	14.4	22.6	16.1	0.57	19.2	27.5	15.4	0.42

The results of participants from each work location reporting 'had discomfort in the last 12 months' was also compared *between* Phase 1 and Phase 3, as shown in Table 30. There was a significant decrease in reported discomfort in the lower back and knee between Phase 1 and

Phase 3 for those working in the Development location at the Control site (Springvale). There was also a significant decrease in reported discomfort in the right shoulder for those working in the Longwall location, and a significant increase in reported discomfort in the lower back for those working in Other locations.

Table 30 – Comparison of percentage of participants who 'had discomfort in the last 12 months' across different body regions, between Phase 1 and Phase 3 at the Development, Longwall and Other locations at the Control site (Springvale)

Body region	Development			Longwall			Other		
	Phase 1 (n = 90)	Phase 3 (n = 125)	*p*-value	Phase 1 (n = 31)	Phase 3 (n = 40)	*p*-value	Phase 1 (n = 62)	Phase 3 (n = 26)	*p*-value
Neck	34.4	24.0	0.11	41.9	30.0	0.30	37.1	38.5	0.91
Right shoulder	25.6	18.4	0.21	25.8	5.0	0.01*	25.8	22.1	0.69
Left shoulder	18.9	14.4	0.37	22.6	12.5	0.25	9.7	23.1	0.14
Right wrist/Hand	11.1	12.8	0.66	19.5	15.0	0.62	17.7	19.2	0.83
Left wrist/Hand	10.0	10.4	0.93	12.9	12.5	0.97	21.0	15.4	0.44
Upper back	14.4	12.0	0.67	19.3	15.1	0.64	16.1	15.4	0.91
Lower back	52.2	37.6	0.030*	41.9	37.5	0.67	37.1	61.5	0.04*
Hip/Thigh	11.1	9.6	0.82	25.8	17.5	0.42	12.9	11.5	0.86
Knee	41.1	24.8	0.01*	32.3	32.5	0.98	35.5	38.4	0.79
Ankle/Foot	14.4	19.2	0.33	22.6	27.5	0.63	16.1	15.4	0.91

*indicates significant at p <0.05

Participants at the Control site (Springvale) reported whether the cause of musculoskeletal discomfort was the result of a work-related or non-work related accident (Table 31). Overall, there was a trend toward a reduction in discomfort due to both non work-related accidents and work-related accidents between Phase 1 and Phase 3. This reduction in reported musculoskeletal discomfort was significant in both the right shoulder and knee, for both non-work related and work-related accidents. A comparison of discomfort as a result of work-related accident between Phase 1 and Phase 3 is presented in Figure 11.

Table 31 – Comparison of the percentage distribution across different body regions of those responding 'Yes' for the cause of discomfort owing to work-related or non-work related accidents between Phase 1 and Phase 3 at the Control site (Springvale)

Body region	Non-work related accidents (Sporting/Home activity/others)			Work-related accidents		
	Phase 1	Phase 3	*p*-value	Phase 1	Phase 3	*p*-value
Neck	14.2	9.8	0.18	26.2	18.6	0.07
Right shoulder	18.0	8.9	<0.01*	16.4	9.3	0.04*
Left shoulder	11.6	11.3	0.92	10.4	7.8	0.37
Right wrist/Hand	10.4	7.5	0.32	10.9	12.3	0.67
Left wrist/Hand	7.6	5.0	0.29	8.2	8.3	0.97
Upper back	5.6	6.0	0.87	8.7	5.4	0.20
Lower back	25.2	20.5	0.29	34.4	25.5	0.06
Hip/Thigh	8.3	6.4	0.47	6.7	5.9	0.75
Knee	22.3	11.9	<0.01*	29.5	19.6	0.02*
Ankle/Foot	14.2	12.3	0.53	12.6	15.7	0.38

*indicates significant at $p < 0.05$

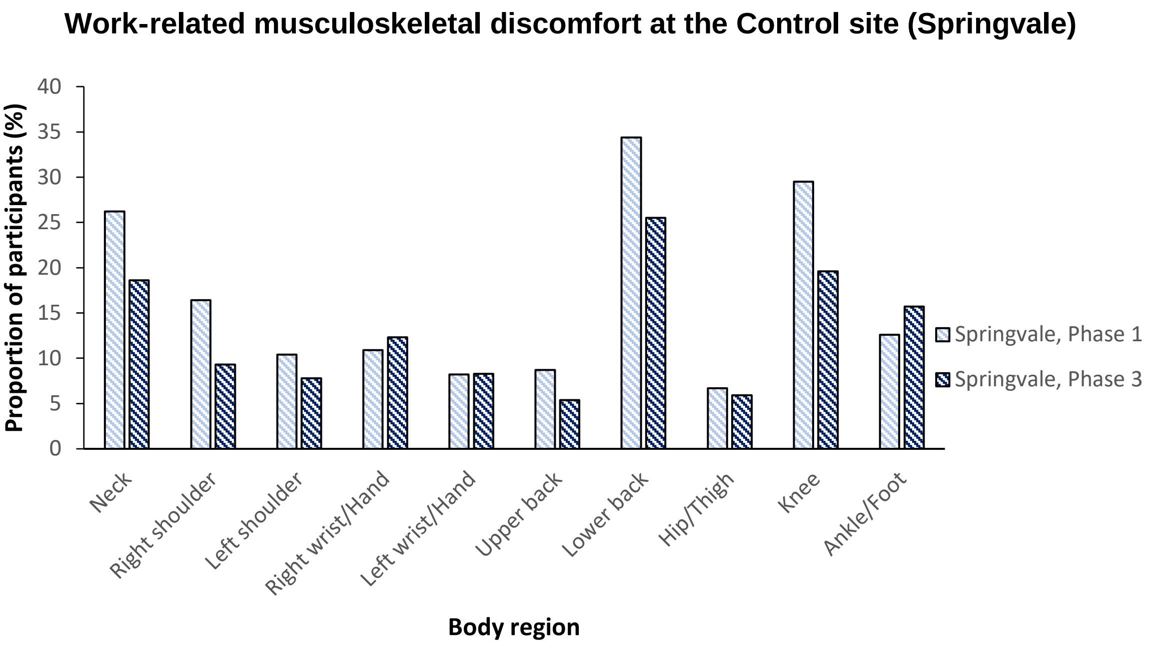

Figure 11- Comparison of the percentage of participants responding 'Yes' over the cause of discomfort owing to work-related accident across each body region between Phase 1 and Phase 3 at the Control site (Springvale)

Self-reported levels of pain were recorded using a pain score where '0 = no pain' and '10 = the worst pain ever' in each of the body regions. This was calculated for whole of body pain for each participant and transformed to a score out of 100, with lower scores indicating less pain and higher scores indicating more pain. The distribution of categorised total pain scores is reported in Table 32. There was a significant reduction in number of participants reporting a score of 20 – 30 between Phase 1 and Phase 3, however in the categories of zero pain, 0 – 10, 30 – 40 and 40+, the reported pain levels increased between Phase 1 and Phase 3.

Table 32 – Comparison of the distribution of total self-reported pain scores between Phase 1 and Phase 3 at the Control site (Springvale)

Pain Score	Phase 1 (n = 183)	Phase 3 (n = 203)	Difference
0	12	13.8	-1.8
>0 and ≤10	31.7	33.9	-2.2
>10 and ≤20	35	28.6	6.4
>20 and ≤30	17.5	7.9	9.6*
>30 and ≤40	2.7	6.9	-4.2
>40	1.1	3	-1.9

*indicates significant at p <0.05

Job Content Questionnaire (JCQ)

The main components of the job strain model (29) were included in the survey with questions related to skill discretion, decision authority, psychological job demands and support.

Table 33 provides the results of the JCQ for the Control site (Springvale) at Phase 1, Phase 2 and Phase 3. A higher number of participants indicated they had very low skill discretion, and moderate levels of decision authority between phases, however there was no significance difference between Phase 1 and Phase 3 scores.

Table 33 – Comparison of JCQ scores across the four categories between each Phase at the Control site (Springvale)

Category	Phase 1 (%)	Phase 2 (%)	Phase 3 (%)	Difference between Phase 1 and Phase 3
Skill discretion				
Very low	9.8	13.9	6.8	-3
Low	59.6	51.9	58.9	-0.7
Moderate	29.5	33.2	33.3	3.8
High	1.1	1.0	1.0	-0.1
Decision Authority				
Very low	15.3	20.7	19.3	4
Low	25.7	27.4	24.0	-1.7
Moderate	38.3	33.2	40.6	2.3
High	20.8	18.8	16.2	-4.6
Psychological job demand				
Very low	9.8	22.6	9.9	0.1
Low	47.5	63.9	52.1	4.6
Moderate	34.4	13.0	28.1	-6.3
High	8.2	0.5	9.9	1.7

4.3 Comparison of results from the Intervention site (Mandalong) and the Control site (Springvale) between Phase 1 and Phase 3

A comparison of the number and average age of participants and who participated in the study at the Intervention site (Mandalong) with the Control site (Springvale) at Phase 1 and at Phase 3 is shown in Table 34. There is no significant difference in the number or the mean age of those who participated between the sites or the Phases.

Table 34 – Number and average age of participants the Intervention site (Mandalong) and the Control site (Springvale) at Phase 1 and Phase 3

	Phase 1		Phase 3	
	Mandalong	Springvale	Mandalong	Springvale
No. of participants	259	185	239	203
Average age (Standard deviation)	43.5 (10.8)	42.4 (10.4)	43.5 (10.4)	42.0 (10.7)

Table 35 compares the number of participants by current role at both sites, and at Phase 1 and Phase 3. Overall, the distribution of participants by their current role is similar at both sites, and includes a good cross section of participants from all other job roles.

Table 35 – Distribution of participants by current role at the Intervention site (Mandalong) and the Control site (Springvale) at Phase 1 and Phase 3

Current role	Phase 1		Phase 3	
	Mandalong	Springvale	Mandalong	Springvale
Electrician	28	22	29	22
Fitter	37	27	28	23
Deputy	34	17	32	18
Miner	137	97	143	124
Other	21	20	7	16

Table 36 compares the number of participants by shift at both sites, and at Phase 1 and Phase 3. At the Intervention site (Mandalong), there is a good cross-section of participants across all shifts. At the Control site (Springvale), there are relatively fewer participants from weekend shifts who participated in the survey. In particular, the number of participants from weekend night shift is under-represented in Phase 3.

Table 36 – Distribution of participants by shift at the Intervention site (Mandalong) and the Control site (Springvale) at Phase 1 and Phase 3

Shift	Phase 1		Phase 3	
	Mandalong	Springvale	Mandalong	Springvale
Afternoon	53	54	44	57
Day	52	46	48	63
Night	53	52	49	49
Weekend Day	47	17	45	29
Weekend Night	52	12	53	3

Table 37 compares the number of participants by location of work at both sites, and at Phase 1 and Phase 3. The majority of participants worked at the Development location at both sites. The distribution of participants by location of work is similar at both Phases. There are fewer participants working at the Development and at both Development and Longwall (combined) locations at the Control site (Springvale), compared to the Intervention site (Mandalong).

Table 37 – Distribution of participants by location of work at the Intervention site (Mandalong) and the Control site (Springvale) at Phase 1 and Phase 3

Location	Phase 1		Phase 3	
	Mandalong	Springvale	Mandalong	Springvale
Development	151	90	165	125
Longwall	35	31	34	40
Development and Longwall	30	9	25	6
Other	30	29	10	20

Psychological distress

Psychological distress was measured by participant K10 scores. Figure 12 provides an overview of the scores at Phase 1 at each site, showing the percentage of participants reporting low, moderate, high and very high levels of psychological distress. Also included is a comparison with the levels of psychological distress observed in those who are currently employed at other mines (27), and currently employed Australians (28). At Phase 1, there were more participants at the Intervention site (Mandalong) reporting low and moderate levels of psychological distress compared to the Control site (Springvale) participants, and less participants reporting high and very high levels of psychological distress compared to the Control site (Springvale).

At both sites, levels of psychological distress are similar to data collected from other coal mines (27). However, levels of low psychological distress are lower than currently employed Australians and levels of moderate, high and very high psychological distress are higher than currently employed Australians (28).

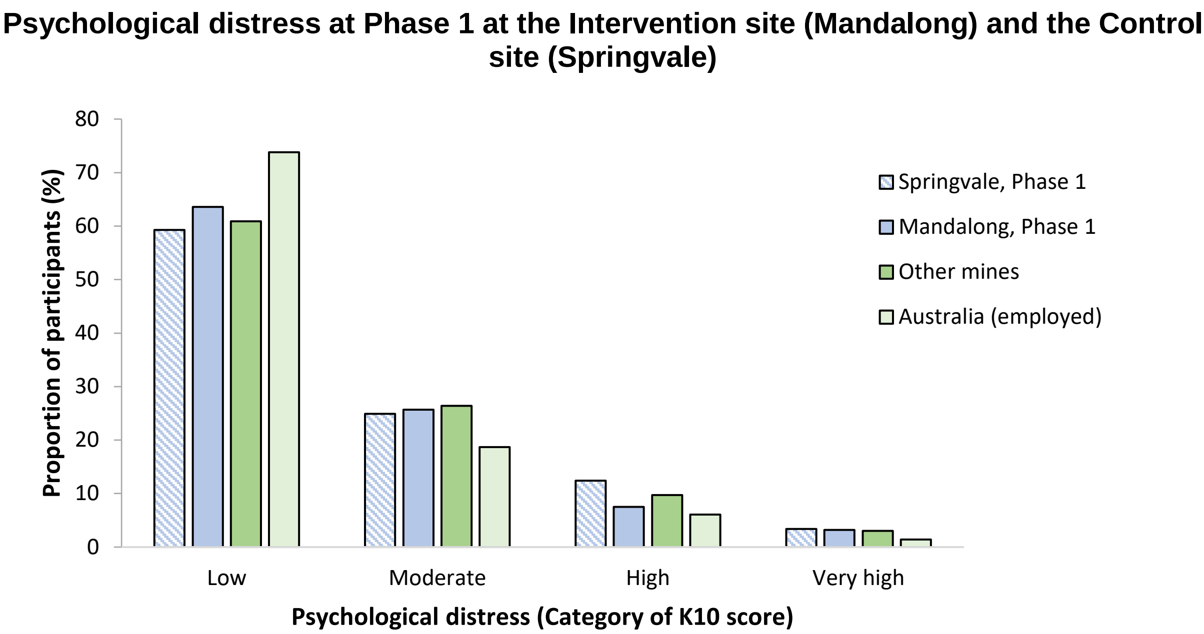

Figure 12 – Comparison of proportion of participants in each psychological distress (K10) category at Phase 1 between the Intervention site (Mandalong), the Control site (Springvale), employed Australians, and employees at other mine sites

Figure 13 provides an overview of the scores at Phase 3 at each site, showing the percentage of participants reporting low, moderate, high and very high levels of psychological distress. Also included is a comparison with the levels of psychological distress observed in those who are currently employed at other mines (27), and currently employed Australians (28). At Phase 3, there were less participants at the Intervention site (Mandalong) reporting low levels of psychological distress compared to the Control site (Springvale) participants, and more reporting moderate, high or very high levels of psychological distress compared to the Control site (Springvale).

Comparable to Phase 1, at both sites, levels of psychological distress are similar to data collected from other coal mines (27). However, levels of low psychological distress are lower than currently employed Australians and levels of moderate, high and very high psychological distress are higher than currently employed Australians (28).

Psychological distress at Phase 3 at the Intervention site (Mandalong) and the Control site (Springvale)

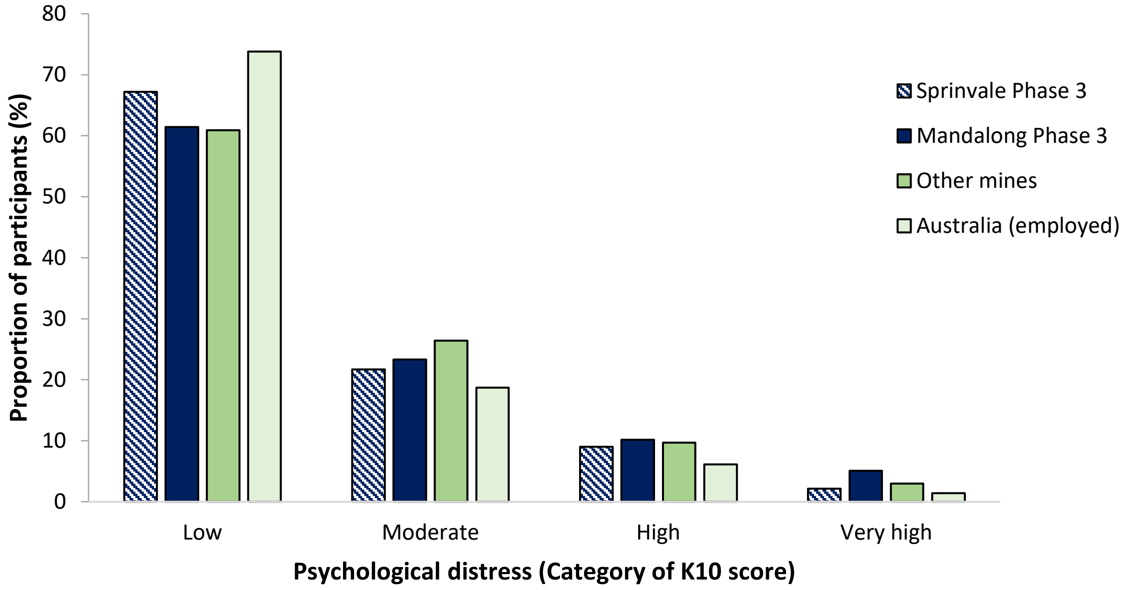

Figure 13 – Comparison of proportion of participants in each psychological distress (K10) category at Phase 3 between the Intervention site (Mandalong), the Control site (Springvale), employed Australians, and employees at other mine sites

The distribution of the participants across the four categories of psychological distress, at Phase 1 and Phase 3, is shown in Table 38. The percentage difference between each distress category at the Intervention site (Mandalong) and Control site (Springvale) at each Phase is also reported. There is no significant difference in psychological distress at any category between Intervention site (Mandalong) and Control site (Springvale) participants at either Phase 1 or Phase 3.

Table 38 – Percentage distribution of participants by psychological distress category (K10); Comparison of the Intervention site (Mandalong) to the Control site (Springvale) at Phase 1 and Phase 3

Category	Phase 1			Phase 3		
	Mandalong (%) n = 259	Springvale (%) n = 185	Difference (%)	Mandalong (%) n = 239	Springvale (%) n = 203	Difference (%)
Low	63.6	59.3	4.3	61.4	67.2	-5.8
Moderate	25.7	24.9	0.8	23.3	21.7	1.6
High	7.5	12.4	-4.9	10.2	9.0	1.2
Very High	3.2	3.4	-0.2	5.1	2.1	3.0

Fatigue

At Phase 1, there was a significantly lower level of fatigue at the Intervention site (Mandalong) when compared to the Control site (Springvale). At Phase 3, the scores were reversed with the Intervention site (Mandalong) reporting significantly *higher* average levels of fatigue compared to the Control site (Springvale). At each Phase, and at each site, the average fatigue score was less than that of the normal population (>54). Table 39 shows the differences between each site at Phase 1 and Phase 3.

Table 39 – Comparison of average fatigue score between participants at the Intervention site (Mandalong) and the Control site (Springvale) at Phase 1 and Phase 3

Fatigue Score	Phase 1			Phase 3		
	Mandalong	Springvale	Difference	Mandalong	Springvale	Difference
Average (CI)	38.1 (35.0 – 41.0)	44.5 (40.9 – 48.1)	-6.4*	42.7 (39.4 – 46.1)	38.0 (34.7 – 41.2)	4.7*

*indicates significant at $p < 0.05$

Quality of Life

Summary statistics of the four QOL domains at the Intervention site (Mandalong) and the Control site (Springvale) at Phase 1 and Phase 3 are presented in Table 40. Higher scores indicate higher QOL.

At Phase 1 and at Phase 3, the scores across the physical, psychological, and environmental domains was slightly higher at the Intervention site (Mandalong) than the Control site (Springvale), and slightly lower at the Intervention site (Mandalong) at both Phases in the social domain. There were however no statistical differences between the two sites at either Phase 1 or Phase 3 in any of the four domains.

Table 40 – Summary statistics of QOL scores by domain, and difference between the Intervention site (Mandalong) and Control site (Springvale) at Phase 1 and Phase 3

Domain	Phase 1			Phase 3		
	Mandalong	Springvale	Difference	Mandalong	Springvale	Difference
Physical Health	72.8	70.2	2.6	68.8	64.9	3.9
Psychological	66.4	66.0	0.4	69.1	69.0	0.1
Social Relationship	72.3	74.4	-2.1	69.4	72.0	-2.6
Environment	71.7	69.9	1.8	68.9	66.7	2.2

Musculoskeletal Discomfort

The Nordic Musculoskeletal Questionnaire results for Mandalong and Springvale have been compared at Phase 1 and at Phase 3.

Table 41 presents the results of participants reporting having ‘ever had any discomfort’ across all body regions, comparing Phase 1 at the Intervention site (Mandalong) to Phase 1 at the Control site (Springvale); and comparing Phase 3 at the Intervention site (Mandalong) to Phase 3 at the Control site (Springvale). As shown, there are no significant differences between the two sites at either Phase 1 or Phase 3. There are a fewer percentage of participants reporting having ‘ever had discomfort’ at the Intervention site (Mandalong) than the Control site (Springvale) at both Phase 1 and Phase 3, with the exception of the ankle and left shoulder in Phase 1 and the neck and both shoulders in Phase 3, where a higher percentage of Intervention site (Mandalong) participants reported discomfort than the Control site (Springvale).

Table 41 – Comparison between percentage of participants from the Intervention site (Mandalong) and Control site (Springvale) who have ‘ever had any discomfort’ across different body regions, at Phase 1 and Phase 3

Body region	Phase 1			Phase 3		
	Mandalong (%) (n = 257)	Springvale (%) (n = 183)	Difference (%)	Mandalong (%) (n = 239)	Springvale (%) (n = 203)	Difference (%)
Neck	43.6	50.8	−7.2	40.1	39	1.1
Right shoulder	36.2	36.1	0.1	30.6	21.5	9.1
Left shoulder	34.2	25.8	8.4	26.0	22.4	3.6
Right wrist/Hand	17.2	21.9	−4.7	15.3	19.5	−4.2
Left wrist/Hand	10.5	19.1	−8.6	11.2	16.6	-5.4
Upper back	13.6	19.1	−5.5	12.0	15.6	−3.6
Lower back	52.9	63.4	−10.5	46.3	52.2	-5.9
Hip/Thigh	15.6	21.3	−5.7	12.0	14.6	−2.6
Knee	42.0	47.0	−5	39.3	41.5	−2.2
Ankle/Foot	30.0	26.2	3.8	21.9	26.3	−4.4

Table 42 and Figure 14 present the results of participants reporting having ‘had discomfort in the last 12 months’ across all body regions, comparing Phase 1 at the Intervention site (Mandalong) to Phase 1 at the Control site (Springvale); and comparing Phase 3 at the

Intervention site (Mandalong) to Phase 3 at the Control site (Springvale). As shown, there are no significant differences between the two sites at either Phase 1 or Phase 3. There are however, at Phase 1, less percentage of participants at the intervention site (Mandalong) reporting discomfort in all areas except the left shoulder when compared to the Control site (Springvale). At Phase 3, there were less percentage of participants at in Intervention site (Mandalong) reporting discomfort in all areas except the neck and right and left shoulders when compared to the Control site (Springvale).

Table 42 – Comparison between percentage of participants from the Intervention site (Mandalong) and Control site (Springvale) who have 'had discomfort in the last 12 months' across different body regions, at Phase 1 and Phase 3

Body region	Phase 1			Phase 3		
	Mandalong (%) (n = 257)	Springvale (%) (n = 183)	Difference (%)	Mandalong (%) (n = 239)	Springvale (%) (n = 203)	Difference (%)
Neck	31.1	36.6	−5.5	31.4	27.8	3.6
Right shoulder	23.7	25.7	−2	22.3	16.1	6.2
Left shoulder	23.4	16.4	7	17.8	15.6	2.2
Right wrist/Hand	9.7	14.8	−5.1	9.5	14.6	-5.1
Left wrist/Hand	7.8	14.3	−6.5	6.2	12.2	−6
Upper back	9.7	15.9	-6.2	9.5	13.2	-3.7
Lower back	42.0	45.4	-3.4	38.8	41.5	-2.7
Hip/Thigh	11.7	14.2	-2.5	9.5	11.7	-2.2
Knee	31.1	37.7	-6.6	29.8	29.8	0
Ankle/Foot	21.8	16.4	5.4	17.4	20.5	-3.1

Figure 14 shows the percentage of participants who 'had discomfort in the last 12 Months' across different body regions, at the Intervention site (Mandalong) and the Control site (Springvale) at both Phase 1 and Phase 3.

Comparison of musculoskeletal discomfort 'in the last 12 months' between the Intervention site (Mandalong) and the Control site (Springvale) at Phase 1 and Phase 3

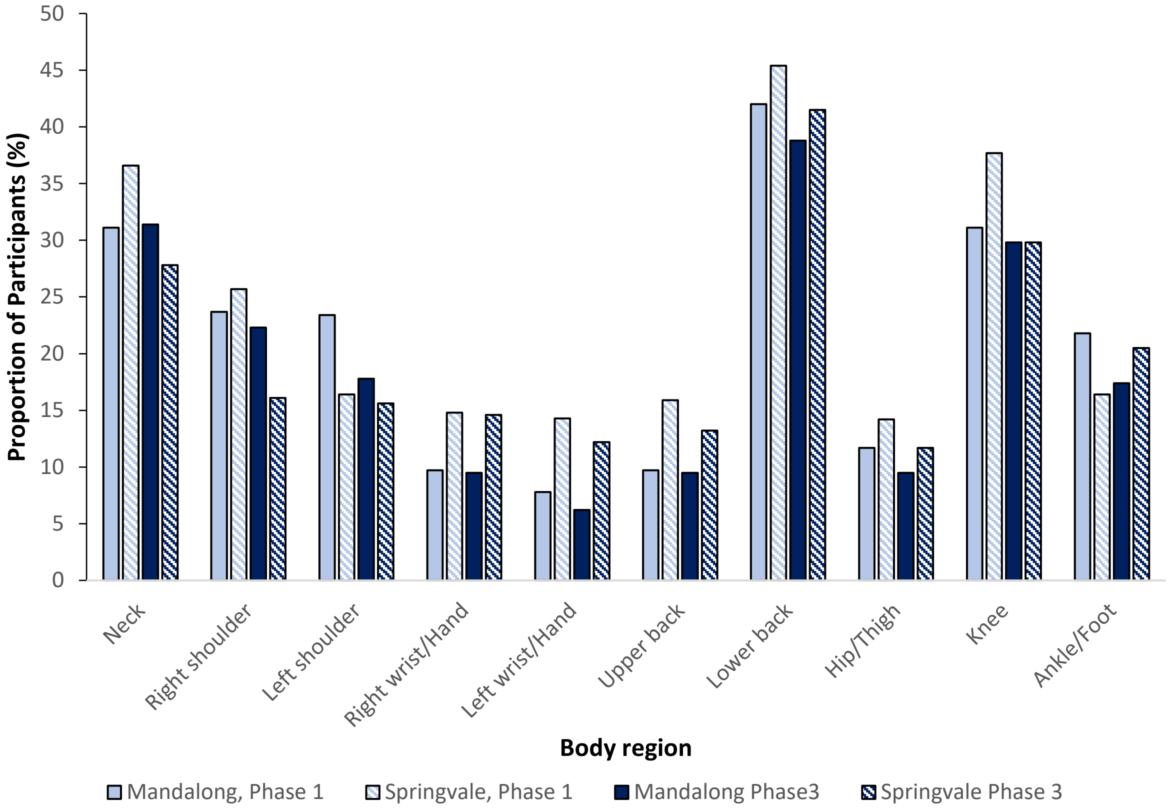

Figure 14 – Percentage of participants who reporting having 'had discomfort in the last 12 months' across different body regions, at the Intervention site (Mandalong) and the Control site (Springvale) at both Phase 1 and Phase 3

Table 43 and Figure 15 provides the results of those who reported the cause of musculoskeletal discomfort being a work-related accident at both sites, and at Phase 1 and Phase 3. A significantly higher percentage of Intervention site (Mandalong) participants reported left shoulder discomfort from a work-related accident compared to Control site (Springvale) participants at Phase 1. At Phase 3, a significantly higher percentage of participants at the Intervention site (Mandalong) reported knee discomfort due to a work-related accident compared to Control site (Springvale) participants.

Table 43 – Comparison of percentage distribution across different body regions of those responding 'Yes' to a work-related accident being the cause of discomfort between participants at the Intervention site (Mandalong) and the Control site (Springvale) at Phase 1 and Phase 3

Body region	Phase 1			Phase 3		
	Mandalong (%) (n = 257)	Springvale (%) (n = 183)	Difference (%)	Mandalong (%) (n = 239)	Springvale (%) (n = 203)	Difference (%)
Neck	23.0	26.2	-3.2	21.9	18.6	7.6
Right Shoulder	17.5	16.4	1.1	16.2	9.3	7.1
Left shoulder	17.1	10.4	6.7*	13.2	7.8	2.6
Right wrist/hand	9.3	10.9	-1.6	8.7	12.3	-1.4
Left wrist/hand	7.0	8.2	-1.2	5.4	8.3	-0.1
Upper back	8.2	8.7	-0.5	7.0	5.4	3.3
Lower back	31.1	34.4	-3.3	25.6	25.5	8.9
Hip/Thigh	8.2	6.7	1.5	5.0	5.9	0.8
Knee	30.0	29.5	0.5	24.4	19.6	9.9*
Ankle/Foot	16.3	12.6	3.7	11.6	15.7	-3.1

*indicates significant at p <0.05

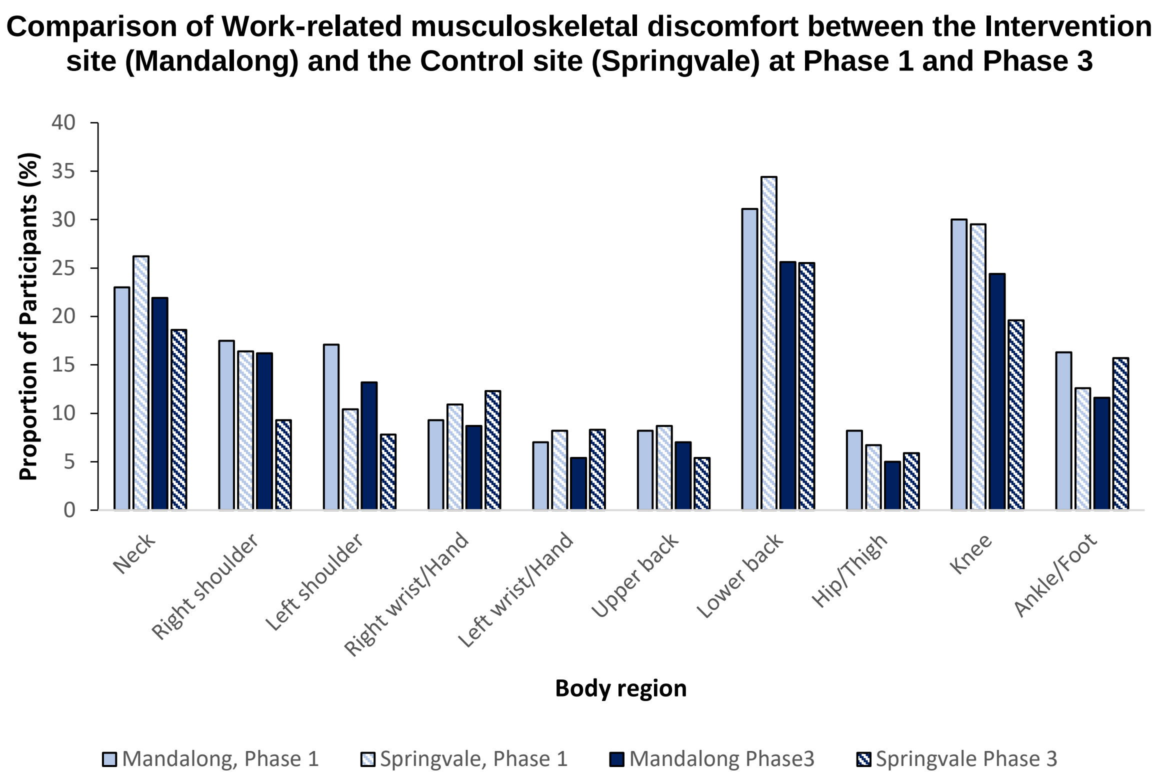

Figure 15 – Percentage of participants responding "Yes" to a work-related accident being the cause of discomfort at the Intervention site (Mandalong) and the Control site (Springvale), at Phase 1 and Phase 3

Self-reported levels of pain were recorded using a pain score where '0 = no pain' and '10 = the worst pain ever' in each of the body regions. This was calculated for whole of body pain for each participant and transformed to a score out of 100, with lower scores indicating less pain and higher scores indicating more pain. The comparison between total scores at the Intervention site (Mandalong) and the Control site (Springvale) at both Phase 1 and Phase 3 is reported in Table 44. There were significantly less participants reporting a score of 10 – 20 at the Intervention site (Mandalong) at Phase 1, and significantly more reporting zero pain at Phase 3 compared to the Control site (Springvale).

Table 44- Comparison of the distribution of total self-reported pain scores between the Intervention site (Mandalong) and the Control site (Springvale) at both Phase 1 and Phase 3

Pain Score	Phase 1			Phase 3		
	Mandalong (n = 257)	Springvale (n = 183)	Difference	Mandalong (n = 239)	Springvale (n = 203)	Difference
0	10.9	12.0	-1.1	21.3	13.8	7.5*
>0 and ≤10	38.1	31.7	6.4	33.5	33.9	-0.4
>10 and ≤20	24.5	35.0	-10.5*	23.0	28.6	-5.6
>20 and ≤30	17.1	17.5	-0.4	10.9	7.9	3
>30 and ≤40	5.5	2.7	2.8	6.7	6.9	-0.2
>40	3.9	1.1	2.8	4.6	3	1.6

*indicates significant at *p* <0.05

Job Content Questionnaire (JCQ)

The main components of the job strain model (29), including questions related to skill discretion, decision authority, psychological job demands and support were included in the survey.

Table 45 provides the results of the JCQ, comparing the Intervention site (Mandalong) to the Control site (Springvale) at both Phase 1 and Phase 3. Psychological job demand was the only area where there were any significant differences, at the low and moderate levels at both Phases. At Phase 1, the Intervention site (Mandalong) had a significantly higher percentage of individuals scoring in the low level of psychological job demand compared to the Control site (Springvale), and a significantly lower percentage of individuals scoring in the moderate range compared to the Control site (Springvale).

This was similar at Phase 3, with the Intervention site (Mandalong) having a higher percentage of individuals scoring in the low levels, and a lower percentage scoring in the moderate levels of psychological job demands than those at the Control site (Springvale).

Table 45- Comparison of JCQ scores across the four categories between the Intervention site (Mandalong) and the Control site (Springvale) Phase 1 and Phase 3

Category	Phase 1			Phase 3		
	Mandalong n = 259	Springvale n = 185	Difference	Mandalong n = 239	Springvale n = 203	Difference
Skill discretion						
Very low	7.0	9.8	-2.8	10.2	6.8	3.4
Low	57.6	59.6	-2	58.5	58.9	-0.4
Moderate	32.3	29.5	2.8	29.7	33.3	-3.6
High	3.1	1.1	2	1.7	1.0	0.7
Decision Authority						
Very low	12.1	15.3	-3.2	13.6	19.3	-5.7
Low	23.0	25.7	-2.7	27.5	24.0	3.5
Moderate	42.4	38.3	4.1	41.5	40.6	0.9
High	22.6	20.8	1.8	17.4	16.2	1.2
Psychological job demand						
Very low	17.1	9.8	7.3	10.2	9.9	0.3
Low	61.1	47.5	13.6*	67.0	52.1	14.9*
Moderate	17.9	34.4	-16.5*	16.1	28.1	-12*
High	3.9	8.2	-4.3	6.8	9.9	-3.1

*indicates significant at $p < 0.05$

5 Discussion

Task rotation can be used by workplaces to control the level of exposure to hazards that individual workers experiences while at work such as repetitive lifting and sustained postures. The impact of task rotation on reducing work-related injuries, discomfort and fatigue is not well defined in the coal mining industry. Underground coal mines are complex workplaces where multiple factors must be taken into account, and understanding the interplay of factors involved in implementing a task rotation schedule effectively is critical to its success. This study aimed to investigate the effects and challenges to implementing a task rotation schedule at a whole of site level in an underground coal mine (Mandalong) by comparing this to a Control mine (Springvale) over a 12 month period.

Data was collected at both the Intervention site (Mandalong) and the Control site (Springvale) prior to implementation (Phase 1), mid-way through intervention (Phase 2) and at the conclusion of the study (Phase 3).

5.1 Participants

The two samples were representative of other samples from the coal mining industry. Age, current role, location of work and shift type was consistent across all three phases of the study at both the Intervention (Mandalong) and Control (Springvale) sites. There were however, relatively fewer participants from the weekend shifts, particularly weekend night shift, at both Phase 2 and Phase 3 at the Control site (Springvale).

There was no significant difference in mean age at either site or across all three phases. The distribution of participants by current role was similar at both sites, and included a good cross section of positions from the different job roles.

5.2 Psychological distress

Participants' mental health and psychological distress was evaluated using the K10 questionnaire. At all Phases, at both the Intervention site (Mandalong) and the Control site (Springvale), participants were asked to report their level of feeling over the last four weeks. The scores were stratified into four categories of low (10 – 15), moderate (16 – 21), high (22 – 29) and very high (30 – 50).

Psychological distress at the Intervention site (Mandalong) and the Control site (Springvale)

Psychological distress in the Intervention site (Mandalong) participants was found to be consistent with observed levels from other mining studies (27, 30), however this is noticeably higher than an age and gender weighted sample of employed Australians (28). Although psychological distress was not a primary outcome of this study, it is interesting to note there was a slight, non-significant increase in those reporting high and very high levels of psychological distress over the three phases.

At the Control site (Springvale), psychological distress in the participants was also found to be consistent with observed levels from other mining employees (27, 30), which is also noticeably higher than an age and gender weighted sample of employed Australians (28). Over the 12 month period there was an increase in those reporting low levels of psychological distress and a corresponding decrease in those reporting moderate, high, or very high levels of distress over the three phases which indicates that psychological distress levels of the group as a whole improved over the study period.

Psychological distress comparison

There was no significant difference in psychological distress scores at Phase 1 or Phase 3 between the Intervention site (Mandalong) and the Control site (Springvale). This indicates that the intervention did not have an effect on psychological distress. It should be noted that the levels of psychological distress identified at both sites was higher than the average population of working Australians (28). Results parallel that of recent cross-sectional examination of psychological distress in eight Australian coal mines (27, 30) where similar rates of moderate and higher levels of psychological distress in mining employees were found)33.1% to 49.5%(.

There was some level of improvement in psychological distress levels at the Control site (Springvale), with less percentage of participants reporting moderate and higher levels of psychological distress over the twelve month period. Conversely, at the Intervention site (Mandalong) the incidence of reported moderate and higher levels of psychological distress increased slightly.

Factors associated with psychological distress in Australian coal miners have previously been outlined and include: being single; previous diagnosis of a mental health disorder; risky alcohol use; current smoker; poor social networks; decreased work satisfaction; concerns about job security; the level of mental health support available; and working in mining primarily for financial reasons (27, 30). It is likely that these factors, external to the task rotation intervention, may have influenced the changes in psychological distress scores.

During the time of the task rotation intervention, there has been an industry wide focus and prioritisation on mental health issues in the mining industry in conjunction with the National Blueprint for Mental Health and Wellbeing (31), which provides a clear framework to assist in addressing mental health issues in mining employees. Improvement in scores may have been influenced by this recent prioritisation of mental health issues within the mining industry and potentially at the sites involved in this study.

In addition, the Development consent (Land, Environment and Planning consent) for the Control site (Springvale mine) was under legal challenge during the time of the task rotation project. This was subsequently approved but after a retracted process of appeals and disputes, when the future of the mine and therefore of the participants' employment was under a cloud. Understandably, this may have had an effect on the psychological distress levels of the participants at the Control site (Springvale).

Fatigue has been identified as one of the influencing factors of psychological distress (32), with workers experiencing fatigue being significantly more likely to miss work and experience greater absenteeism (33).

5.3 Fatigue

Fatigue was measured using the eleven-item ‘Need for Recovery after Work’ scale with dichotomous responses. Fatigue levels were negatively scored, with higher scores indicating higher levels of fatigue (34).

Fatigue at the Intervention site (Mandalong) and the Control site (Springvale)

Fatigue levels at the Intervention site (Mandalong) increased slightly during the 12 month study period, although there was no significant difference in reported fatigue levels between Phase 1, Phase 2 and Phase 3. At all Phases the mean fatigue scores reported were below the cut-off point of >54 (34).

Fatigue levels at the Control site (Springvale) decreased between Phase 1 and Phase 2, and then increased between Phase 2 and Phase 3. When considering change over the 12-month study period there was a slight decrease in mean fatigue scores between Phase 1 and Phase 3. At all Phases the mean fatigue scores reported were below the cut-off point of >54 (34).

Fatigue comparison

When comparing the fatigue scores at the Intervention site (Mandalong) and the Control site (Springvale) at Phase 1, before the task rotation intervention, there was a significantly lower level of fatigue at the Intervention site (Mandalong). This was reversed at Phase 3 when the Intervention site (Mandalong) reported a significantly higher average level of fatigue than at the Control site (Springvale).

Analysis of the structure and task components of the rotation scheme may provide a potential explanation for the increase in fatigue score at the Intervention site (Mandalong). It is highlighted that effective task rotation depends on how biomechanical stressors are balanced. It is possible that if workers rotate from one task which places excessive load on their lower back to another task placing stress in a similar area, the rotation scheme will be ineffective in controlling injury and fatigue risk. Thus, for a beneficial task rotation scheme, tasks should be dissimilar and alternate physical demands (7).

Coal miners' fatigue has been identified as a physiological and psychological phenomenon relating to a variety of factors including: work load, poor working environments, monotonous tasks, and mental and emotional burdens (35). Work conditioning may also have been a factor in the fatigue levels observed in this study, with higher levels of fatigue observed in the Intervention site (Mandalong) participants at Phase 3 (at the conclusion of the task rotation intervention). It may be that participants had the opportunity to complete a larger variety of tasks during this period and, for some of these tasks, the individual participant may not have become conditioned to the physical demands of that specific task. Fatigue has also been identified as a factor that can increase physical and mental effort and impair the ability of workers to meet job demands, thus resulting in increased risk of being involved in occupational accidents (36).

In addition, the effects of shift work have been linked to increases in fatigue. Akerstedt (2003) (37) reported shift workers are at an increased risk of developing fatigue and disturbed sleep and noted that the effects of shift work appear to linger, affecting workers on subsequent days. Carlisle and Parker (2014) (32) identified that fatigue, alongside decreased sleep quality, increased the reporting of distress by coal miners during work periods. In the present study, many of the participants worked shift work, with weekend-working participants completing longer hours. This was consistent over the period of the study and over the task rotation intervention, therefore shift length is not considered a factor that impacted upon the change in fatigue levels seen in this study.

Increased levels of fatigue in the Intervention site (Mandalong) contrast that of the findings from the small pilot study, which reported that participants in the intervention group experienced a decrease in fatigue levels post-task rotation (17). These contrasting results may relate to the selection of participants, considering that the pilot study only assessed participants working on night shift, opposed to the whole-of-site approach used in the present study.

5.4 Quality of Life

The WHOQOL-BREF assesses the QOL within the context of an individual's culture, value systems, personal goals, standards and concerns and is divided into four domains of physical, psychological, social relationships and environment (22, 24). The domains of the WHOQOL-BREF were positively scored, a higher score indicates a higher perceived QOL.

Quality of Life at the Intervention site (Mandalong) and the Control site (Springvale)

At the Intervention site (Mandalong) there were significant differences found between Phase 1 and Phase 3 in the physical and environmental domains, with the mean QOL scores for these domains reducing over the 12 month intervention period, indicating that participants had a lower reported QOL at Phase 3. In the psychological domain there was a significant difference in mean QOL scores, with an increase between Phase 1 and Phase 3 suggesting improvements in psychological health over this time period. In all four domains the scores at the Intervention site (Mandalong) were lower than that of Australian norms (22).

At the Control site (Springvale), participant scores for the physical, and environmental domains were significantly lower at Phase 3 compared to Phase 1. Mean QOL score of the social relationship domain reduced over the study period, but this was not significant. In relation to the psychological domain there was a statistically significant increase at Phase 3 compared with Phase 1 which may have been influenced by the legal challenges to the Land and Environment Development consent that was taking place at the time of the study, with a resolution to the issues by the Phase 3 time point where participants scores higher on the psychological domain indicating improvements in this aspect of their quality of life. With the exception of the social relationship domain which scored similarly to the Australian norms, the scores for participants at the Control site (Springvale) in the psychological, physical and environmental domains were lower than that of the Australian norms (22).

Quality of Life comparison

When comparing the results between the Intervention site (Mandalong) and the Control site (Springvale), there were no statistical differences in QOL between the two sites at Phase 1 or Phase 3 in any of the four domains. In all 4 domains, the scores were lower than Australian norms. with the exception of the social relationship domain at Phase 1 and Phase 3 (22).

The scores across the physical, psychological and environmental domains was slightly higher at the Intervention site (Mandalong) compared to the Control site (Springvale), indicating a higher QOL for those participants at both the Phase 1 and Phase 3. The scores in the psychological domain were similar at both sites at both Phase 1 and Phase 3. Between time-points, both sites experienced reductions in scores pertaining to the physical health and environment domains; increases in the psychological domain, and no significant change in the social relationship domain.

The physical health domain of the WHOQOL-BREF encompasses facets relating to a participants energy and fatigue, sleep and rest, mobility, pain and discomfort, and work capacity (22). Physical health scores reduced at both the Intervention (Mandalong) and Control (Springvale) sites between Phase 1 and Phase 3. However, there were no significant differences when comparing between sites at either time-points. The non-significant reduction in physical health scores at both sites indicates that task rotation did not have a real impact upon these scores, and other issues may have been influencing the physical health of the participants at both sites. As the physical health domain also includes aspects of fatigue it is interesting to note that the findings of an increase in fatigue levels at the Intervention site (Mandalong) correspond with lower scores in the physical health domain of the QOL. However, this is not consistent with the findings at the Control site (Springvale) where fatigue levels improved.

The psychological domain of the WHOQOL-BREF incorporates the participants' thinking, learning, memory, concentration, and self-esteem (22). Scores on the psychological domain of the WHOQOL-BREF improved between Phase 1 and Phase 3 at both the Intervention (Mandalong) and Control (Springvale) sites. However, there were no significant differences between sites at either phase. These results contrast findings from the K10, which reported an increase in psychological distress levels at the Intervention site (Mandalong). A possible explanation for this difference may stem from considering what each tool attempts to measure.

The psychological domain focusses on body image and appearance, negative feelings, positive feelings, self-esteem, spirituality and religion, and cognitive function (22). Whilst the psychological domain of the WHOQOL-BREF provides a well-rounded, multi-faceted perspective on an individual's psychological health, the K10 serves as a global measure of distress based on specific questions about anxiety and depressive symptoms. Task rotation as an intervention did not aim to address any psychological aspects, and K10 scores were used to allow comparison across the sites and industry as a whole.

It is interesting to note that the findings relating to the psychological domain in this study are in contrast to the findings in a sample of female cashiers and employees of a manufacturing company, where workers were “stimulated”, “concentrated” and “happy” (8, 38).

The environment domain of the WHOQOL-BREF encompasses the participants’ physical environment as well as their financial resources, health and social care, and opportunities for acquiring new information and skills (22). Scores from the environment domain of the WHOQOL-BREF reduced at both the Intervention (Mandalong) and Control (Springvale) site between Phase 1 and Phase 3, and there was no significant difference between the sites at either time points. The environment domain incorporates aspects that are not likely to be significantly affected by a task rotation intervention such as financial resources, health care access and quality, transport, and home environment. However, opportunities for acquiring new information and skills could have been expected to have been influenced by task rotation. Improvements in skill development have been found in other task rotation studies with findings identifying that job rotation provided greater opportunities for employees to develop their skills and increase their level of knowledge (8, 38).

There were no significant differences in the mean social relationship domain scores between time points for both the Intervention (Mandalong) and Control (Springvale) sites, or between sites at Phase 1 and Phase 3. However, at both sites the scores in this domain reduced from Phase 1 to Phase 3. Considering the main objective of task rotation is to minimize biomechanical stress, limit worker boredom and fatigue, and increase employee satisfaction (5-7), significant changes to participants’ social relationship domain of the QOL was not expected.

This study identified a disparity between the mining participants at both sites and the Australian public. This is evident when comparing participants’ QOL scores to the reported Australian norms (22). At both Phase 1 and Phase 3, QOL scores at the Intervention site (Mandalong) and the Control site (Springvale) were below that of the Australian norms for each of the 4 domains (22). These results are consistent with the literature, which identifies the increased safety risks associated with the difficult and demanding environment that miners must negotiate on a day to day basis (2-4). This may also be an indication of the attitudes of those that work in mining in general. For example, a study of coal miners in central Queensland found that job satisfaction has a strong positive effect on life satisfaction (39).

5.5 Musculoskeletal discomfort

The Nordic Musculoskeletal questionnaire asked the participants to report their musculoskeletal symptoms during the last 12 months and the last 7 days that impacted on their daily activities (18).

Musculoskeletal discomfort at the Intervention site (Mandalong) and the Control site (Springvale)

At the Intervention site (Mandalong), the lower back, knee and neck were the regions of the body with the highest rates of reported musculoskeletal discomfort in 'the last 12 months', which related to the period of task rotation implementation. There were reductions in reports of musculoskeletal discomfort during the previous 12 months in all body regions, with the exception of the neck, between Phase 1 and Phase 3. A slight increase in neck discomfort was reported.

When the results are considered by location of work at the conclusion of the task rotation period at the Intervention site (Mandalong), there was a significant difference in the reported discomfort in 'the last 12 months' between those that worked at the Development, Longwall or Other locations of the mine. Specifically in the knee, where results showed higher levels of discomfort for those working in Other locations of the mine when compared to the Development location, and even less when compared to those working at the Longwall location. The floor conditions in the different locations of the mine, with some areas being more consistent, may have had an impact on this result alongside different tasks completed in the different locations being more or less demanding on the knee.

The results at the Intervention site (Mandalong) at Phase 1 were compared to Phase 3 at the Development location with no significant differences across any of the body regions identified. Likewise, at the Longwall location there were no significant differences across body regions between Phase 1 and Phase 3. However, the Other location of the mine showed a significant increase in knee discomfort over the 12 month period of the task rotation, although the sample was small in this area which may have influenced the results.

At the Intervention site (Mandalong), there was a significant reduction in reported discomfort to the ankle/foot between Phase 1 and Phase 3 due to reported non-work related accidents. Overall there was a reduction in those participants reporting discomfort as a result of a work-related accident between Phase 1 and Phase 3 across all body regions, with the most commonly reported injury being to the lower back, knee, and neck.

At the Control site (Springvale), similarly to the Intervention site (Mandalong) the lower back, knee and neck were identified as the body regions with the highest reported musculoskeletal discomfort during 'the last 12 months'. There were reductions in reports of musculoskeletal discomfort during 'the last 12 months', in all body regions with the exception of the ankle/ foot, between Phase 1 and Phase 3, where a slight increase in ankle discomfort was reported.

When the results are considered by location of work at the conclusion of the task rotation period (Phase 3) at the Control site (Springvale), there was no significant difference in the reported discomfort in 'the last 12 months' between those that worked at the Development location, the Longwall location, or Other areas of the mine.

The results at the Control site (Springvale) were compared for Phase 1 and Phase 3 at the Development location with a significant difference found in the lower back and in the knee. At the Longwall location of the mine a significant difference between Phase 1 and Phase 3 was found in the right shoulder and in the Other locations of the mine, a significant difference was found in the lower back region of the body.

At the Control site (Springvale), when considering reports of non-work related discomfort there was a significant reduction in reported injuries to the right shoulder and in the knee between Phase 1 and Phase 3. This was also seen in those reporting work-related discomfort with a significant reduction in discomfort in the right shoulder and in the knee. The most commonly reported discomfort was to the lower back, knee, and neck.

Musculoskeletal discomfort comparison

When comparing the musculoskeletal discomfort results from the Intervention site (Mandalong) and the Control site (Springvale) over the duration of the task rotation intervention (Phase 1 to Phase 3), no significant differences were found in musculoskeletal discomfort in any body region.

At both sites the lower back, knee, neck, shoulders and ankle were the most commonly reported regions to experience discomfort. This is consistent with findings from Safe Work Australia who reported that the highest workplace injury incidents across all industries in Australia occurred in the back (22%), hand (13%), shoulder (10%) and knee (9%) (40). Further to this, Safe Work Australia reported high prevalence of back strain injuries, accounting for a significant percentage of serious claims in Australian agriculture, forestry and fishing (14%), manufacturing (18%), health and community services (26%) and mining industries (21%) for the 2010 – 2012 time period (40). Back injuries were also identified as the largest workplace injuries in New Zealand (18%) (41) and Canada (16%) (42). However, direct comparison is difficult as a result of differences in definitions and data collection methods used across various countries (43).

Although back pain is the most prevalent reported workplace injury across Australian industry, 35% of the participants in the current study reported back pain, a rate higher than the national average (22%). Brinckmann *et al.* (44) reported high rates of lower back pain among miners may be common and suggested it was a result of a high exposure to awkward postures, heavy manual work, and exposure to whole-body vibration that exists in the mining work environment. This finding is supported by the National Institute for Occupational Safety and Health who identified that rates of back injuries in underground mining were more than double those of surface mining, and higher than most other industries (45).

The reports of musculoskeletal discomfort were slightly less at the Intervention site (Mandalong) than Control (Springvale) at Phase 1 and Phase 3, with the exception of the ankle and left shoulder at Phase 1 and in the left and right shoulder and neck at Phase 3.

Overall, musculoskeletal discomfort was reduced in all body regions except the neck at Phase 1, however there were no statistically significant reductions. This is similar to results reported after a task rotation schedule was implemented in a manufacturing sample (46), and may be indicative of the overall ambiguity surrounding the benefits of task rotation on musculoskeletal discomfort (47, 48). A series of studies investigating the effect of task rotation in refuse collecting contexts have reported similar results relating to the physical health of participants (12-14). Rotation schedules implemented in these studies led to reduced cardiovascular loads (13) and non-neutral working postures (12), but an increased number of lower back pain complaints. It was thought that while rotations distributed the physical load among workers, it subsequently increased the number of workers exposed to higher loads (14). Jorgensen *et al*. (7) highlighted that effective task rotation depends on how biomechanical stressors are balanced. If workers rotate from one task which places excessive load on their lower back to another task placing stress in a similar area, the rotation scheme will be ineffective in controlling injury and fatigue risk. Thus, for a beneficial task rotation scheme, tasks should be dissimilar and alternate physical demands.

When considering musculoskeletal discomfort as a result of a work related cause, there was a significant difference in percentage of participants who reported a left shoulder work related injury at Phase 1, with more participants reporting this at the Intervention site (Mandalong) than Control (Springvale). At Phase 3 there was a significantly higher percentage of participants at Mandalong reporting knee discomfort as related to a work related accident. With reference to the findings of discomfort due to a work-related cause from this study, (Figure 15), and the areas of reported discomfort (Figure 14), the knee is the second most commonly reported area of discomfort. These results correspond with a significant increase in knee discomfort in those working in the Other location of the mine.

Injury at the Intervention site (Mandalong)

There was no significant difference between reported incidence of injury between the 12 month period prior to the task rotation and the task rotation intervention period, with injury rates being similar at both time points. The most common injury experienced during the task rotation intervention period was to the knee which corresponds to the reports from the Nordic questionnaire (18), where reported knee discomfort was significantly more at Phase 3 when compared to Phase 1; and to the larger percentage of participants reporting knee injury as a result of a work related cause.

The lower back, neck, knee and shoulder were the most commonly reported body regions experiencing injury, and this corresponds to the Safe Work Australia information with the highest workplace injury incidents across all industries in Australia being in the back (22%), hand (13%), shoulder (10%) and knee (9%) (40). In addition, between 2001-02 and 2014-15; body stressing due to handling, carrying and putting down objects, represented 39% of all worker's compensation claims in the Australian mining industry (4).

The most common cause of injury was falls, trips or slips, followed by overexertion, with most injuries resulting in strains and sprains. This is also consistent with data from the Australia mining industry where falls, trips and slips accounted for 25% of injuries, followed by 18% involving impact by a moving object (4).

Over the last decade, the introduction of new technology, along with heightened concerns for safety, has resulted in significant reductions in injury rates. Despite this, mining still ranks high amongst the formal economy sectors for work related fatalities, injuries and illnesses (2).

5.6 Job Content Questionnaire

The survey used a modified version of the JCQ (21) to determine a perceived ratio between job demands and job resources. Job Demands refers to task requirement and work load; job control refers to the ability the worker has to control their work activities and decision autonomy; and demands and control determine the psychological strain at work (21). Scores were stratified within categories with Skill Discretion stratified into very low (0-7), low (8-11), moderate (12-14) and high (15-16). Decision Authority and Psychological Job Demand scores were stratified into very low (0-6), low (7-8), moderate (9-10) and high (11-12). Job Support score was stratified into very low (0-2), low (3-4), moderate (5-6) and high (7-8).

JCQ at the Intervention site (Mandalong) and the Control site (Springvale)

At the Intervention site (Mandalong), more participants indicated they had very low Skill Discretion and slightly less had high levels of Skill Discretion when comparing Phase 1 and Phase 3, however this was not significantly different. Similarly, there were some non-significant changes in Decision Authority, with less participants reporting high levels of decision authority at Phase 3. When considering the Psychological Job Demands, there was a significant difference in the very low levels reported between Phase 1 and Phase 3.

At the Control site (Springvale), a higher percentage of participants indicated they had very low Skill Discretion and moderate levels of Decision Authority between Phase 1 and Phase 3. However, this was not significantly different.

JCQ Comparison

A comparison of the two sites showed there were no significant differences between Intervention and Control in the Psychological Job Demands aspect of the JCQ at both Phase 1 and Phase 3, at the low and moderate levels.

The Intervention site (Mandalong) had a higher percentage of participants scoring in the low level of the psychological job demand at Phase 1 (61.6%), compared to 47.5% at the Control site (Springvale). Conversely, the Intervention site (Mandalong) had a lower percentage of participants scoring in the moderate level of psychological job demand at Phase 1 (17.9%), compared to 34.4% at the Control site (Springvale). At Phase 3, this was similar with the Intervention site (Mandalong) having a higher percentage of individuals scoring in the low levels, and less in the moderate levels of psychological job demands than those at the Control site (Springvale).

There was an overall increase at each site between Phase 1 and Phase 3, which may be as a result of an inherent difference between the two sites and perhaps contributes to the effectiveness of implementing the task rotation intervention at the Intervention site (Mandalong). Vermeulen and Mustard (49) found in a study of gender differences in Job Strain, that compared with low-strain work, high-strain and active work were associated with a significantly higher level of distress in both men and women. In addition, workers with jobs characterised by high demands, low decision latitude and low social support have a higher risk of poor psychological well-being and cardiovascular diseases.

It is identified that the most adverse reactions of psychological strain occur when the psychological demands are high and the worker's decision authority is low (21). However, in this study, more participants reported low or moderate psychological demands and most reported moderate decision authority, which suggests the environment of this study is less conducive to reactions of psychological strain.

It has also been suggested that there is ‘good stress’ which involves active behaviour development under conditions of high demands and high decision authority. This is known to predict motivation, new learning behaviours, and coping pattern development and conversely low demands coupled with low decision authority result in a lack of motivation leading to negative job learning or gradual loss of previously acquired skills (21). As the results at both sites sit in the middle of these extremes it can be suggested that overall jobs are appropriately demanding in these aspects and the task rotation intervention did not change the perception of skill discretion, decision authority or psychological job demands.

5.7 Weekly Schedule at the Intervention site (Mandalong)

During the task rotation intervention period, records of who completed which task during each shift was recorded, however these schedules were not always complete, with some shifts in some areas of the mine providing a more complete record than others.

At the Development location of the mine, when considering the number of tasks an individual completed, on average, most of the participants were able to complete two different tasks during the shift (afternoon, day, night, weekend night), with those working weekend day shift being able to complete three. However the range of days that participants completed one, two, or three rotations is very wide.

When considering the specific tasks at the Development location, the LH and RH bolter were most commonly completed by three participants (62.8% and 68.5% of the time respectively), followed by the Miner driver and Shuttle Car driver. The LH offsider and Supplies were most commonly completed by two individuals during the shift (55.7% and 53.7% respectively). This shows that of the tasks at the Development location, most were rotated three times a shift during the task rotation intervention period.

This indicates that at the Development location, each participant was being allocated mostly two different tasks per shift. However, when considering the tasks, some were more commonly rotated three times during the shift. This raises the question as to whether some of the participants were completing longer periods of time doing the one task than others to achieve this result.

At the Longwall location, on average, most of the participants completed only one task per shift on afternoon, day and night shift. However, on the weekend day and weekend night shift participants were able to complete two tasks on average, however the range of days that participants completed one or two rotations is very wide.

When considering the specific tasks at the Longwall location, Trades was most commonly rotated twice per shift (83.6% of the time), followed by the Chock Operators (76.8 & 72%), Shearer driver (70%) and Boot-end (67%). The Shearer driver and Boot-end were most commonly completed by three different individuals in a shift but this was less than 25% of the time.

Comparing the Development and Longwall locations of the mine showed there was a significant difference in the average number of days that participants completed one, two or three task rotations, with significantly more rotation of tasks at the Development location.

The number of task rotations achieved during a shift in this study is less than that recommended in the literature. Asensio-Cuesta *et al* (9) completed a study on rotation schedules aimed at preventing work related musculoskeletal disorders in repetitive work (9), their study recommended that there should be approximately four rotations during an eight hour shift. In addition, Raina and Dickerson (10) recommended three task rotations during an eight hour shift, with rotations up to every 30 minutes for high intensity manual tasks (10). Padula, Comper (15) completed a systematic review of job rotation in manufacturing industries and identified that extensive analysis of activities needs to be involved in a task rotation scheme to ensure scheduling is selected, and implemented, based on the specifics of job components and individual worker characteristics (15).

It should be noted that the three rotation per shift schedule was developed with the participants, taking into consideration what was practical and feasible for them within this dynamic environment, and appropriate levels that they felt would maintain production and quality of work required. This schedule had also been trialled in the pilot study that demonstrated that a three-segment rotation schedule was feasible and practical within the confines of a dynamic coal mining environment (17).

6 Limitations

A number of limitations with the use of the survey included issues with participants not including an anonymous identifier code that would have allowed a matched-individual analysis over the three surveys and resulted in group analysis of data being completed. This may have been due to concern surrounding confidentiality.

A further limitation at the Intervention site (Mandalong) was the inability to monitor commitment and the actual implementation of the task rotation in the various sections of the workplace. Supervisors on each shift in each section of the intervention mine completed the task rotation schedule logs (as a measure of adherence to the intervention), however as noted in the results there was much incomplete data in this component of the study, with more detail provided in the Development locations than in the Longwall locations. That said however, the support from supervisors improved over the intervention period.

This task rotation schedule was implemented at the Intervention (Mandalong) however further to discussion with the Control (Springvale) site, as part of 'normal' practice they informally include some less structured task rotation on a weekly basis or for the more physically demanding tasks such as the non-production Longwall tasks these are rotated daily. This may have had an impact upon the results particularly when comparing the Intervention (Mandalong) and Control (Springvale) sites.

In addition the different culture between the Intervention (Mandalong) and Control (Springvale) sites and between the various work crews within the Intervention (Mandalong) site may also have had an impact upon the uptake of the task rotation initiative with some individuals being more or less motivated to attempt this rotation.

Another factor that might have impacted upon the task rotation schedule is the available manning within each of the Intervention (Mandalong) crews. As some tasks require individuals to have specific training and expertise, if there was a limit to the number of trained individuals for any one task on a specific shift, or trained individuals were not as competent as others then rotation may have been affected particularly if this was likely to impact upon production. Appropriate levels of training for particular tasks is an aspect of task rotation that needs consideration for full implementation of such a schedule.

The uncertainty related to the life of the mine and therefore ongoing employment for participants at the Control site (Springvale) during the twelve month period of the study may have affected the results specifically relating to issues of wellbeing (and other flow-on factors such as psychological distress and QOL) of the control sample.

The findings from this study need to be considered in light of the limitations and the fact that only two mines were involved. These results can only be generalizable to underground coal mines that implement a similar process of coal extraction and shift patterns. Additional research with a more structured task rotation process would be beneficial to improve validity of these findings.

7 Conclusions

This report outlines the results of the task rotation intervention study at the Mandalong (intervention site) and Springvale (control site) coal mines in NSW.

There was no significant difference in psychological distress scores at Phase 1 or Phase 3 between the two sites. This indicates that the intervention did not have an effect on psychological distress. However, these results parallel that of recent cross-sectional examination of psychological distress in eight Australian coal mines (27, 30) where similar rates of moderate and higher levels of psychological distress in mining employees were found.

In relation to fatigue, the mean fatigue scores increased at the Intervention site (Mandalong) over the study period, with a significantly higher average level of fatigue reported at the conclusion of the study (Phase 3) when compared to the Control site (Springvale). The schedule of task rotation and its implementation may have had an adverse effect on the fatigue of participants as they were doing more variety of tasks with different physical and mental demands over the course of the study and therefore actual schedule of rotation, and the implementation and execution of the schedule may need consideration and potential review to assist in effectively controlling injury and fatigue risk.

There were no differences in QOL scores between the two sites over the study period. Both sites reported a reduction in physical health and environmental domain scores of the QOL at the conclusion of the study, and an increase in scores in the psychological domain. The social relationship domain scores remaining fairly constant. This suggests that the task rotation did not have a significant impact upon QOL. These results are consistent with the literature which identifies the increased safety risks associated with the difficult and demanding environment that miners must negotiate on a day to day basis (2-4).

When comparing the musculoskeletal discomfort reported between the two sites there was no significant differences identified indicating that the task rotation intervention did not have an impact upon musculoskeletal discomfort in either a positive or negative way. However, at the Intervention (Mandalong) site there was a reduction in reported discomfort in all body regions except the neck, over the task rotation period. The implementation of the task rotation schedule may have influenced this with individuals doing a variety of tasks each shift therefore providing variety to the demands upon the body. There was a reduction in reported discomfort over the course of the task rotation in the left shoulder, which corresponds with a reduction in discomfort reported as owing to both a non-work related and work related accidents at the Intervention (Mandalong) site. Alternating tasks that involve shoulder activity such as bolting tasks within the Development unit may have influenced this outcome with less musculoskeletal discomfort reported specifically in the left shoulder over the course of the task rotation period. The knee remained however an area of concern and consideration of the impact of the tasks and the environment upon the knee need further investigation.

Injury rates at the Intervention site (Mandalong) were similar pre- and during the task rotation period, with the most common injury being to the knee. This corresponds with the findings of the study, where reported knee discomfort was significantly higher Phase 3 compared to Phase 1. In addition, a larger percentage of participants reported knee injury as a result of a work-related cause.

There were no significant differences between the two sites on the JCQ aspects of skill discretion or discretion authority however there were significant differences between the psychological demands aspect of the JCQ at both Phase 1 and Phase 3 when comparing the two sites, specifically in the low and moderate ranges. The Intervention site (Mandalong) reported more participants in the low range. As there were differences both at the beginning and end of the task rotation these results are unlikely to have been influenced by this intervention.

The findings from this study need to be considered in light of the limitations. The detail of the amount of task rotation that was actually implemented at the Intervention site was limited by the completion of the task rotation logs with some shifts having more data to analyse than others. Tasks in the Development location were most commonly rotated three times per shift, whereas in the Longwall location tasks were most commonly rotated only twice per shift. The amount of rotation however varied according to the shift, with some shifts logging more rotations than others, which suggests that some crews, on some shifts were more committed to the process of task rotation. When considering the individual workers on each shift there was less data available to analyse. The mean number of rotations per day identified per participant had a very large range i.e. a mean of two rotations per day but a range of 1 to 111 days where this took place.

That said, the fact that this study continued for the 12 month task rotation period in a very dynamic workplace environment is testament to the efforts of those involved and the engagement of management at the Intervention (Mandalong) site. It is acknowledged that doing ‘implementation research’ in a real workplace environment is very challenging.

The actual schedule of rotation, and the implementation and execution of the schedule, may need consideration and potential review to assist in effectively controlling injury and fatigue risk. In addition, supplementary research with a more structured task rotation process would be beneficial to improve validity of these findings.

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