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Age-related Changes in Work Ability and Injury Risk in Underground and Open-cut Coal Miners
Age-related changes in work ability and injury risk in underground and open-cut coal miners

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Underground sites:

Beltana (Xstrata Coal)
Crinum (BMA)
Crinum East (Mastermyne Contractors)
Kestrel (Rio Tinto)
Newlands Underground North (Xstrata Coal)
Newlands Underground South (Xstrata Coal)
Oaky Creek North (Xstrata Coal)
Oaky Creek Number 1 (Xstrata Coal)
United (Xstrata Coal)
Open-cut sites:

Blackwater (BMA)
Bulga Open-cut (Xstrata Coal)
Commodore (Roche Mining)
Ensham (Golding Contractors)
German Creek Open-cut (Anglo Coal)
Gregory (BMA)
Gregory (Golding Contractors)
Mt Thorley/Warkworth (Rio Tinto)
New Acland (New Hope Coal)
Newlands Open-cut (Xstrata Coal)
Norwich Park (BMA)
Oaky Creek Surface (Xstrata Coal - Thiess Contractors)
Ravensworth Operations, Narama (Xstrata Coal)

Thank you also to the mine workers from miscellaneous contract companies who completed the questionnaire. Your time and contribution are much appreciated.
### ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>ABS</td>
<td>Australian Bureau of Statistics</td>
</tr>
<tr>
<td>ACARP</td>
<td>Australian Coal Association Research Program</td>
</tr>
<tr>
<td>ANOVA</td>
<td>analysis of variance (statistical term)</td>
</tr>
<tr>
<td>BCA</td>
<td>Business Council of Australia</td>
</tr>
<tr>
<td>BMP</td>
<td>Bureau of Mining and Petroleum</td>
</tr>
<tr>
<td>CDC</td>
<td>Centres for Disease Control</td>
</tr>
<tr>
<td>CTD</td>
<td>cumulative trauma disorder</td>
</tr>
<tr>
<td>CVD</td>
<td>cardiovascular disease</td>
</tr>
<tr>
<td>df</td>
<td>Degrees of Freedom</td>
</tr>
<tr>
<td>DMR</td>
<td>Department of Mineral Resources (NSW)</td>
</tr>
<tr>
<td>DPM</td>
<td>diesel particulate matter</td>
</tr>
<tr>
<td>FIOH</td>
<td>Finnish Institute of Occupational Health</td>
</tr>
<tr>
<td>HSC/E</td>
<td>Health and Safety Commission/Executive (UK)</td>
</tr>
<tr>
<td>ILO</td>
<td>International Labour Organization</td>
</tr>
<tr>
<td>IPCA</td>
<td>Injury Prevention and Control (Australia) Pty Ltd</td>
</tr>
<tr>
<td>MCA</td>
<td>Minerals Council of Australia</td>
</tr>
<tr>
<td>MSD</td>
<td>musculoskeletal disorder</td>
</tr>
<tr>
<td>MHSA</td>
<td>Mine Safety and Health Administration (US)</td>
</tr>
<tr>
<td>NIOSH</td>
<td>National Institute for Occupational Safety and Health (US)</td>
</tr>
<tr>
<td>NOHSC</td>
<td>National Occupational Health and Safety Commission (Aust)</td>
</tr>
<tr>
<td>NRM</td>
<td>Department of Natural Resources and Mines (QLD)</td>
</tr>
<tr>
<td>OR</td>
<td>odds ratio (statistical term)</td>
</tr>
<tr>
<td>QISU</td>
<td>Queensland Injury Surveillance Unit</td>
</tr>
<tr>
<td>WAI</td>
<td>Work Ability Index</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
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The ageing of the Australian workforce poses particular challenges to the coal-mining industry, in which 60% of the workforce is aged over 40. Preventing injury, reducing its impact, and maintaining good health in an older workforce requires better understanding of the relationships between the capacities of the older worker, the nature of the work demands, and specific injury and health issues.

This project is the first study to address these issues in the Australian coal-mining industry. The objectives of the study were to:

a) determine the match between work demands and work ability in Australian coal mine employees of different ages;

b) determine any differences in medically related factors that may affect work ability and any influence of sector (open-cut vs. underground) and occupational category; and

c) characterise those older miners who have high levels of work ability and low rates of injury, in terms of work history, individual attributes, and work patterns.

Data were gathered through the administration of a cross-sectional survey among a large and representative sample of the Queensland and New South Wales coal-mining workforces. Participants included more than 1800 workers (both direct and contract employees) at 22 mine sites (both underground and open-cut operations).

The Work Ability Index, developed by the Finnish Institute of Occupational Health and validated in international studies across a variety of industries, measures the capacity of workers to meet the physical and mental demands of their work. The Index, included in the survey instrument for the first time in coal mining, was supplemented by industry-specific questions relating to risk factors and exposures. The Work Ability Index score was analysed according to age, mine type and job category.

The results of this study are based on workers’ own reports of their working conditions, workplace exposures, the physical and mental demands of their work, and their health status. They provide a snapshot of self-reported prevalence of injuries, musculoskeletal disorders and other health conditions. Differences in work ability and exposure status between injured and injury-free miners aged 45 and over were also examined.

Increased knowledge of the ageing workforce will contribute to improvements in the management of this important resource through the development and implementation of evidence-based health promotion and injury prevention strategies.

The report includes a series of recommendations in the areas of health, work organisation, work environment, education and training, and research, all aimed at supporting the health and work ability of older miners.
EXECUTIVE SUMMARY

In Australia, more than 80% of the projected workforce growth between 1998 and 2016 will be in those over 45 years of age (ABS, 1999). Economic imperatives for strategies to retain older, productive workers in the workforce include the higher projected dependency ratio and the larger number of retirees, most of whom will be living longer than previously. Thus, new strategies are required to enable those older workers who wish to continue working to do so in a healthy and productive manner, and these must be based on greater understanding of the match between the workplace and the physiological and psychological changes characteristic of the older worker. Failure to achieve this match may adversely affect productivity and longer term health, since work-related illnesses or injuries in which work design and work organisation are significant factors (such as stress and musculoskeletal disorders) are experienced more adversely by older than younger workers and may be significant causes of early retirement (Griffiths, 1999).

Knowledge about age-related decrements in functional capacity is mainly derived from laboratory studies involving the ‘old-old’ (65 plus years), and there is only limited information derived from people in the second half of working life (45 to 65 years). The largest continuous study of the influence of ageing on work ability in this age group, conducted in Finland (Ilmarinen, 1999), indicates that work content, work organisation and work environment are significant factors in declines in work capacity and increased rate of retirement from disability. Although individual differences in functional capacity increase with age, older workers are generally more vulnerable to stress from excessive physical demands and poor work postures (Tuomi et al., 1991) and are less tolerant of nightwork (Harma & Ilmarinen, 1999), high work rates and poor work environments (Parker et al., 2002).

Older workers are also more vulnerable to serious and fatal accidents and are more likely than any other age group to die as a result of an accident at work (Hull, 1996). A comparison of work-related fatal injuries in the US, Australia and NZ (Feyer et al., 2001) indicated that male workers, older workers and those working in mining, agriculture and construction were consistently at higher risk. Miners - particularly older workers - also experience significantly elevated risk of multiple non-fatal injuries (Li et al., 1999). The types of accidents that disproportionately affect older workers include exertion injuries, falls from heights or machines, slips and trips, and being struck by vehicles, machinery or falling objects. The physical capacity of older people to manage physically demanding tasks and avoid hazards is a major factor in such accidents. Occupations which demand heavy physical work (approximately 20-25% of the workforce of industrialised countries) expose older workers, who typically have reduced capacity, to over-exertion injuries and cumulative musculoskeletal damage. The negative effects of overload may also be amplified in restricted work spaces (Gallagher, 2001), extreme temperatures or poor visual conditions (Tuomi et al. 1991). Similarly, long and irregular working hours across the
circadian cycle will induce fatigue and increased risk of injury (Harma & Ilmarinen, 1999).

Preventing injury, reducing its impact, and maintaining good health in an older workforce requires better understanding of the relationships between the capacities of the older worker, the nature of work demands, and specific injury and health issues. This project is the first study to address these issues in the Australian coal-mining industry and had the following objectives:

- **To determine the match between work demands and work ability in Australian coal mine employees of different ages;**
- **To determine any differences in medically related factors that may affect work ability and in relation to type of operation and occupational category; and**
- **To characterise those older miners who have high levels of work ability and low rates of injury, in terms of work history, individual attributes and work patterns.**

This research project was funded by the Australian Coal Association Research Program (ACARP).

A cross-sectional study design was employed through the administration of two survey instruments to a total of 1803 members of the coal-mining workforce in New South Wales and Queensland. Both survey instruments incorporated the Work Ability Index (WAI) developed by the Finnish Institute of Occupational Health. This research tool has been translated into more than 20 languages and has been demonstrated to have both internal and external validity in a large number of published studies, across a variety of industries in many countries. The standard Index questions, which ask respondents to report on their physical and mental abilities to meet the demands of their work, also measure health status according to the presence of injury and disease. These questions were supplemented by a number of industry-specific questions concerning exposure to a number of factors particular to coal mining. To the best of our knowledge, this is the first time the WAI has been utilised in coal mining.

This study attracted a high participation rate among a large and representative sample of the Australian coal-mining workforce. The initial survey was administered on site to 1624 workers in open-cut and underground coal mines in Queensland and New South Wales. Results were analysed according to the WAI score, as well as by age group, mine type (open-cut and underground), and job category.

Based on initial results, a supplementary survey instrument was designed with additional questions relating to work history, in terms of the nature of the tasks in which respondents were involved and the duration, frequency and intensity of exposure to possible risk factors for injury. The risk factors were broadly categorised into areas of work organisation, work environment, and work culture. A number of individual health and psychosocial issues were explored in terms of fitness, nutrition and general well-being, and attitudes to work and
management. The relative effectiveness of current controls for some of these risk factors was rated by respondents on a visual analogue scale. The second survey was also administered on site to a smaller, but equally representative sample of 179 workers. Data analysis focused in particular on differences between injured and injury-free older workers (> 45 years), in regard to their exposure status and WAI scores.

**Age-related changes in work ability**

The WAI score was ascertained for the entire sample, and analysed according to age-group, job category, and mining sector (open-cut or underground). The overall WAI score of 42.3 (± 4.9) indicated a relatively high overall level of work ability in the Australian coal-mining workforce. When the distribution of scores was examined relative to the categories of excellent, good, moderate and poor (derived from the original Finnish studies of older municipal workers), over three-quarters of the sample were in the excellent or good category, with about 43% in the excellent category. Because these original categories were derived only from workers over the age of 45, and because of methodological differences, adjusted values for older miners were also obtained. This led to a reduction in the proportion of the workforce classified in the excellent category to 23%. Fewer than 5% of miners were found to be in the poor category.

The main value of the WAI score, however, is for examining differences within the study sample. In addition to a significantly lower WAI in the underground than the open-cut sector overall, analyses showed a clear reduction in the WAI across age groups (20-29, 30-39, 40-49, and 50-59). The size of this decrease was likely to be an underestimate because of the cross-sectional nature of the study. The decrease in WAI across the age groups was more pronounced in the underground than the open-cut sector, such that older underground miners were found to have significantly lower WAI scores than their open-cut colleagues.

Mechanics/fitters, electricians, operator-maintainer/mine-workers, and deputies all had significantly lower WAI scores than professional/administrative staff in the open-cut sector. This was not true for the underground sector. Open-cut electricians also rated their work ability relative to lifetime best at a lower level than open-cut operator-maintainer/mine-workers.

There was a significant overall decrease across age groups in ratings of work ability with respect to the physical demands of work, being more pronounced in underground than in open-cut miners. Electricians and mechanics/fitters had significantly lower mean work ability with respect to physical demands of work than those in the operator-maintainer/mineworker category.

Underground deputies, electricians and mechanics/fitters had significantly lower mean work ability scores than those in the operator/maintainer and professional/administrative categories, whether in relation to physical or to mental demands of their work.

The duties and work tasks undertaken by respondents were analysed and revealed substantial differences in the amount of physically demanding as
opposed to sedentary work. Mechanics/Fitters reported a high frequency of repetitive physical work, along with underground operator-maintainer/mine-workers, and some job categories had high levels of seated work, including open-cut operator-maintainer/mine-workers, who frequently had driving as a major duty. The differences in the degree of physical activity inherent in the various job categories is reflected in the frequency of reporting of some medical conditions such as cardiovascular conditions.

**Characteristics of injured and non-injured miners**

Analysis of the results from both surveys indicated that those miners 45 years and over with a current injury had a significantly lower WAI than their injury-free counterparts. The difference in WAI scores between injured and injury-free groups was equivalent to 10.2 and 11.7 years of age-related decline in the two samples respectively, when related to the decline observed in the Finnish longitudinal studies.

When comparing the duration, frequency and intensity of tasks over the working life of injured and non-injured groups several differences were apparent. While there were no differences in the duration of experience of a particular task, those with injury rated the intensity and frequency of some tasks higher than those without injury. The tasks rated as more physically demanding included manual handling; pushing, pulling and dragging; bending, twisting and stooping; prolonged work in awkward postures; shovelling; and repetitive work. Previous research has identified these tasks as significant risk factors for musculoskeletal injury and when coupled with a higher frequency of exposure associated with some of these tasks, the results support the hypothesis that greater exposure to physically demanding work is associated with higher rates of injury. No definite cause and effect relationships can be established from this data however and a prospective study in which exposure is measured and related to subsequent injury is required.

Injured miners also reported a range of environmental factors that are potentially conducive to injury. For example, poor visibility, poor illumination, wet conditions and uneven ground were experienced more by injured miners over 45 than their non-injured counterparts.

Comparison of injured and injury-free workers on a range of factors associated with work organisation and culture revealed relatively few differences. For example, injured workers rated their enjoyment of work lower than those who were injury free and were less likely to rate the quality of management as excellent. In addition, injured workers indicated lower ratings of sleep quality over their working life and reported greater difficulties in maintaining fitness.

**Individual health factors and work ability**

The WAI incorporated questions on a range of medical conditions, that respondents indicated had been diagnosed by a doctor. The number of reported conditions was analysed with respect to age, mine type and job categories.
These self-reported conditions could not be confirmed by objective diagnosis and as such the results should be interpreted with caution.

Consistent with industry data, the most commonly reported condition was injury with 20.7% of miners reporting a current injury and with almost half of the respondents indicating injury involving the back. Respiratory (12%), sensory (10%) and cardiovascular conditions (8%) were ranked behind injury and musculoskeletal disorders.

The number of reported injuries increased significantly with age and consistent with industry data, underground workers in general appeared more likely to suffer injury than their open-cut counterparts. There were significant differences in the rate of reported injuries between job categories with underground mechanics and fitters reporting the highest rate of any job category.

Consistent with national population data, there was a clear effect of age group on the reports of cardiovascular conditions (CVCs), with workers in their 50’s reporting more than 10 times the rate of those in their 20’s. Open-cut operator/maintainers had a significantly higher rate of CVCs than underground workers in this category. Hypertension was the most frequently reported CVC and 6.5% of the sample indicated that they had been diagnosed as overweight by a doctor.

The number of reported mental conditions also increased significantly with age and almost 3% of workers reported having one or more mental conditions diagnosed by a doctor.

Three percent of respondents reported a doctor’s diagnosis of either insomnia or sleep apnoea and these problems were reported more frequently in the older workers. Comparison of the numbers of mental and sleep disorders derived from self-reported doctor’s diagnosis or own opinion indicated a significantly higher number in the latter category. This suggests an underreporting of these conditions and the need for greater awareness of these issues at the workplace. The increased number of sleep problems with age is consistent with international data and is particularly pertinent to shift workers who have been shown to have increased sleep problems and reduced tolerance to night shifts with age.

In summary, the results of the investigation have identified significant age-related differences in work ability in both open-cut and underground mining operations, consistent with findings from other industries that have used the WAI. These differences in work ability reflect age-related declines in functional capacity and a higher number of health disorders with age involving the cardiovascular and musculoskeletal systems, together with an increased reporting of sleep and mental disorders. Perhaps not surprisingly, older workers with a current injury had a work ability score lower than their injury-free counterparts. In addition, injured workers reported greater experiences of adverse conditions with respect to the work environment, work organisation, and opportunities to enhance their work ability. The findings confirm the need for increased awareness of the age-related differences in work ability and factors which may accelerate or delay this decline. The increased knowledge of the ageing workforce in the coal-mining industry will contribute to the evidence base
required to better manage this important resource, and implement interventions designed to enable older workers who wish to continue in the workforce to do so without added risk of injury and work-related disease. To this end, the following recommendations have been made relating to themes that emerge from the survey and existing research concerned with the older worker:

**Health**

1. Review the current health surveillance practices within the mining industry with the aim of developing a more preventative and proactive approach to health management, consistent with the needs of older workers.
2. It is recommended that medical assessments incorporate evaluation of psychological and sleep disorders.
3. It is recommended that a more holistic approach to health care be implemented, including measures to promote work ability among older workers.
4. Review the extent to which current regulations provide protection to prevent morbidity (ill-health) in older workers and to protect those who stay in the workforce.

**Work organisation**

5. Physical work demands (e.g. repetitive work, poor work postures, manual handling) should be reduced for older workers consistent with changes in functional capacity.
6. Review the shiftwork arrangements for older workers with respect to the reduction in excessively long hours, and with the aim of providing more flexible arrangements and the opportunity to avoid night work.

**Work environment**

7. Higher priority should be given to the mitigation of harmful work environment variables such as uneven ground, vibration, wet conditions, poor illumination, and poor ergonomics. Where complete mitigation is not possible, tighter exposure standards for older workers should be developed.
8. It is recommended that methods to assess exposure to mechanical loading, awkward postures, and other risk factors for musculoskeletal injury are developed and evaluated.
Education and training

9. It is recommended that the industry implement training programs for managers and supervisors to raise their awareness of the issues facing older workers and to provide information on the principles and processes involved in managing the older worker.

10. It is recommended that the industry enhance the awareness and training of medical personnel in detecting work-related medical problems of older workers.

Research

11. It is recommended that the Industry implement and support a research program designed to address key questions related to the ageing of the mining workforce.
SECTION 1    INTRODUCTION

- Study context
- Background literature
- Study objectives
1.1 STUDY CONTEXT

As part of a worldwide phenomenon in industrialised countries, the ageing of the population presents a series of major challenges to the Australian economy and labour market. By 2003, workers aged 45 to 64 years made up almost one-third (32%) of the Australian labour force, compared to less than one-quarter (23%) in 1983 (ABS, 2004). More than 80% of Australian workforce growth in the next decade is projected to be among those aged over 45 years (ABS, 1999). In addition, Australians tend to exit the labour force at an earlier age than their counterparts in other developed countries (BCA, 2003). By the early 2020s, it is estimated that the number of Australian people retiring will exceed those entering the labour force (BCA, 2003). These demographic changes are of special concern to industries such as coal mining, which are already experiencing skills shortages.

From the perspective of the coal-mining industry, the percentage of older workers continues to increase relative to those in younger age categories. According to ABS Census data, 59% of the combined NSW and QLD coal-mining workforce was over 40 in 2001 (ABS, 2002). In 2003, Coal Services figures show the average age of the NSW coal industry workforce was 43.

As the workforce ages, the coal-mining industry is experiencing unprecedented production demands from export markets, which in turn requires workforce growth. Employment in the Queensland coal-mining industry increased by 25% between 31 December 2003 and 31 December 2004, to a workforce of more than 14,000 (NRM, 2005).

The interactions between work and ageing are particularly evident in industries that involve physically demanding jobs and are organised around the 24-hour cycle, such as mining. Premature retirement is an additional adverse outcome of occupational injury more commonly associated with older workers; an outcome which has significant negative social and economic consequences for both workers and industry (Pransky et al., 2005a). The results of research involving other industries indicate that the inability of older workers to meet the physical demands of their work is a major factor in early retirement. This suggests an urgent need to take appropriate measures to adjust the physical requirements of work consistent with age-related changes in functional capacity, in order to enable workers to remain in the workforce should they choose (Ilmarinen, 2002).

Although some studies have shown that older workers typically experience a lower frequency of injury, their injuries tend to be more severe, involve longer recovery periods and higher costs (Laflamme & Menckel, 1995; Hull et al., 1996; McDonald & Harder, 2003; Gauchard et al., 2003; Pransky et al., 2005a). Other studies report a higher incidence of injury in older workers, with sprain and strain injuries associated with overexertion more commonly experienced by those over 45 years (Parker et al., unpublished). Workers’ compensation costs arising from these injuries are a significant burden on the Australian coal industry.
On the other hand, older workers may be of particular benefit to industry in terms of the skills and experience they bring to their work and which they can pass on to the next generation. In addition, there is evidence to indicate that older workers tend to have lower absentee and turnover rates, combined with higher levels of job satisfaction, than their younger counterparts (Pransky et al., 2005b). While the ageing process cannot be reversed, improvements can be made to work organisation, work design and work practices to better accommodate and sustain an ageing workforce.

The need to maintain and expand the workforce and implement new strategies consistent with retention of the skills and experiences of a relatively older mining workforce is obvious. Thus, new strategies are required to assist those miners who wish to continue working to do so productively and with good health, and these must be based on greater understanding of the match between the workplace and the physiological and psychological changes characteristic of the older worker. Retaining within the industry the skill and experience accumulated over long careers is also dependent on such knowledge. Failure to achieve this match may adversely affect productivity and longer term health, since work-related illnesses or injuries in which work design and work organisation are significant factors (such as stress and musculoskeletal disorders) have more adverse effects on older than younger workers and may be significant causes of early departure from the industry (Griffiths, 1999).

The development and evaluation of such strategies should be evidence based and informed by data specific to the Australian coal-mining industry. Towards this goal, this report presents the results of two cross-sectional surveys of work ability and ageing conducted among almost 1800 open-cut and underground coal-mining employees in Queensland and New South Wales.

The concept of ‘work ability’, the extent to which an individual worker’s capacity matches the demands imposed by work tasks, is defined by the question:

How good is the worker at present and in the near future, and how able is he/she to do his/her job with respect to work demands, health and mental resources? (Ilmarinen & Tuomi, 1992).

The Work Ability Index, an instrument to measure work ability, was developed by Ilmarinen et al. (1991) for a major follow-up study of ageing municipal workers in Finland and subsequently used by the Finnish Institute of Occupational Health (FIOH) in a series of longitudinal studies of thousands of ageing workers (e.g. Ilmarinen et al., 1991; Tuomi et al., 1991; Ilmarinen & Tuomi, 1993; Ilmarinen et al., 1997; Tuomi et al., 1997; Ilmarinen & Rantinen, 1999; Tuomi et al., 2001). Considered to be the largest and most consistent research effort on the ageing worker (Kilbom, 1999), initial results showed that high physical work demands and poor physical work environments (both features of the coal-mining industry) were major determinants of lower work ability scores (Tuomi et al., 1991).
The Index, discussed in further detail in the following section, has been used to track changes in work ability among ageing workers in various industries around the world.

While the ageing of the workforce and the potential for age-related influences on injury and work-related disease is recognised in the Australian coal mining industry, almost no systematic information has been obtained on these issues through which appropriate interventions may be implemented. While a limited number of individual mines have trialled various initiatives to assist older workers, these efforts are mainly taking place without any substantial evidence base or evaluation. It has been recognised internationally that determining ways of maintaining work ability, productivity, good health, and high quality of life for employees is an important research task (Kilbom, 1999).

To the best of our knowledge, the current study is the first to use the Work Ability Index either in Australia or in coal mining. In the survey instruments developed, standard Index items were supplemented with questions about industry-specific work tasks and work demands in order to elicit an extra level of information directly from the workforce.

The results of this study will provide evidence to enable the coal-mining industry to move from a base of minimal knowledge into a more informed position with respect to understanding — and therefore addressing — the needs of older workers.
1.2 BACKGROUND LITERATURE

The main focus of this study is the impact of ageing on the work ability of a representative sample of the Australian coal-mining industry workforce. The following section briefly reviews the research literature in the context of the ageing of the workforce and the demands of work, utilising evidence gathered from other industries. An overview is provided in the domains of work environment, work content, work organisation and health of the workforce. This is followed by a discussion of the Work Ability Index, the primary study instrument for the current research project.

1.2.1 Work environment

Coal mining is conducted in an inhospitable work environment with many inherent health risks from physical, chemical, biological and ergonomic hazards (Donoghue, 2004). Underground mine hazards include the need to work in restricted or confined spaces, the possibility of an explosion or cave-in, electric shock, exposure to harmful gases and dust, poor visibility and substantial ventilation challenges (Farrar, 2001). Large and powerful machinery and equipment further exacerbate the potential for accidents, as well as generating coal and silica dust particles and diesel particulate matter, which can have detrimental health effects.

In open-cut mines, although generally less hazardous than the underground environment, workers are subject to handling heavy machinery and equipment and are exposed to outdoor work in all weather conditions. In addition, surface mining relies extensively on explosives to uncover coal deposits, posing a further hazard not present in underground operations (Bajpayee et al., 2004).

Geological hazards such as ignitions, explosions, roof falls, rib falls and rock bursts have been the cause of major tragedies in most coal-producing regions of the world (Hower, 2005). Uneven surfaces, common to both types of mining operation, are responsible for a large proportion of all injuries in coal-mining, representing a significant environmental risk factor (NRM, 2005).

Whether in underground or open-cut operations, coal industry workers may be exposed to extremes of temperature. In deep underground mines, the temperatures of both air and virgin rock are higher, largely due to geothermal gradient, increased barometric pressure and auto-compression of the air column (Donoghue, 2004). Although the deepest mines are not those in the coal sector, high temperatures are nonetheless frequently encountered underground. Levels of perceived exertion and thirst have been shown to be more pronounced in older workers, who are generally less tolerant to hot environments and dehydrate at a faster rate (Marszalek et al., 2005). Older workers (over 45) respond to work-heat stress with higher heart rates, slower heart rate recovery, higher skin and core temperatures, and lower sweat rates than their younger colleagues. These factors place added strain on the cardiovascular system. Men over 45 working in a hot environment have been shown to have higher
physiological costs and lower work ability than younger workers (Marszalek et al., 2005).

The effects of thermal stress have important implications for issues of heat exhaustion and dehydration, especially among underground miners (Donoghue & Bates, 2000; Brake & Bates, 2003). In turn, dehydration can lead to a range of physical, mental and psychological decrements in work performance (Brake & Bates, 2003).

Particularly in underground mining, exposures to coal dust, methane, crystalline silica and diesel particulate matter (DPM) are each hazardous to health (Donoghue, 2004). A major epidemiological study analysing death certificate data from 27 US states identified a significant association between silica exposure (in industries such as mining and quarrying) with increased risk of lung cancer, chronic obstructive pulmonary disorder (COPD), tuberculosis and rheumatoid arthritis (Calvert et al., 2003). While pneumoconiosis rates in Australia have declined significantly since the 1950s, and time lags between exposure and death have increased, there were still some 750 new cases reported between 2001 and 2003, mostly from the mining or manufacturing industries (AIHW, 2005). Despite significant advances in exposure control, 92 Australians died from pneumoconiosis in 2003 (AIHW, 2005).

Many of the compounds contained in diesel exhaust are bio-transformed to DNA-damaging agents (Knudsen et al., 2005) and have been shown in scientific studies to be carcinogenic (Frumkin & Thun, 2001). A case control study of Estonian shale-oil miners showed significant differences ($p < 0.001$) between underground and surface workers in exposure to these agents, with underground miners showing a 7.5-fold higher exposure to particle-associated 1-NP (considered to be one of the more specific markers of diesel exposure) according to DNA samples measured in a laboratory (Knudsen et al., 2005).

Prolonged exposure to diesel exhaust has been associated with increased risk of lung cancer, with mine workers identified as a particularly high-risk group (Gustavsson et al., 2000; Frumkin & Thun, 2001). Occupational DPM exposure has also been identified as an influential factor for cardiovascular death (Virtanen & Notkola, 2002). While steps have been taken in Australia to monitor and limit workplace exposure, some of the latest DPM-minimising technology, currently in use in underground metalliferous mines, is unsuitable for underground coal mines due to risk of explosion (Mackie, 2005).

Coal mines can be particularly noisy workplaces, with hearing loss an additional occupational hazard. Studies conducted in the NSW coal-mining industry in the 1990s found that more than 40% of the workforce had a compensable level of noise-induced hearing loss (Leigh & Morgan, 1990; Worksafe, 1994). Recent Coal Mines Insurance statistics indicate that deafness has accounted for between 60% and 75% of all occupational disease claims since 2001-02 (Coal Mines Insurance, 2005).

In the UK, a cross-sectional study of 22,194 randomly selected working age adults examined the relationship between hearing loss, persistent tinnitus and
exposure to noise (Palmer et al., 2002). The prevalence rates increased both with age and according to years spent in noisy occupations and were particularly evident in men approaching retirement. Severe hearing difficulty among men aged 35 to 64 years was almost 3 times more prevalent in those who had ever worked in a noisy job compared to those who had not.

Age-related changes, whether pathologic or normative, can increase the susceptibility of older workers to environmental hazards (Wegman & McGee, 2004). Where possible, it is preferable to modify the working environment to accommodate the needs of workers rather than attempt to adapt the workers to the environment (Wegman & McGee, 2004).

1.2.2 Work content

Mining, by its very nature, is arduous. Despite increasing mechanisation, most categories of work in coal mining have significant physical demands with intermittent strenuous physical effort required in the course of a work shift. This includes repetitive lifting, shovelling, carrying, stooping and climbing; pushing and pulling of high and heavy loads; operating heavy machinery; and handling awkward materials, such as cabling or ventilation materials. Workers may perform these tasks over long periods of time, with considerable repetition and often with poor working postures. In spite of significant improvements in ergonomics and job redesign in mining, physical strength and stamina consistent with the demands of the work are necessary to prevent acute and overuse musculoskeletal injury (Parker & Worringham, 2004a).

For some workers, however, much more time is spent operating machinery and driving vehicles than in the past, and it has been shown that a significant number of neck and lower back injuries are precipitated by “rough rides” or whole-body vibration (McPhee, 2004). Load factors are also significant in mining, especially underground, where the machinery and equipment is heavy and for safety reasons the use of lighter materials such as aluminium is not permitted (McPhee, 2004).

On the basis of the results of a longitudinal study of municipal workers showing decreases in work ability with age, it is also suggested that older workers should be provided with increasing opportunities to regulate their own work (Ilmarinen, 2004). This would include the order of work tasks, the methods and speeds at which they are undertaken, and the opportunity for more latitude in terms of the timing of work breaks.

The results of research on the physiological demands of specific jobs and information on the age-related deficits in functional capacity can be used to match the worker to the work demands. This may require an adjustment of work demands which may enable individuals to continue working without undue risk of injury. Unfortunately, most industries, including mining, do not adjust the work in this manner. For example, an analysis of the physical demands experienced by Australian underground coal miners (Parker & Worringham, 2004a) indicated that older workers were exposed to the same physical demands as their younger
counterparts. A survey of countries in the European Union indicated that relatively few differences were found between younger and older workers in their exposure to vibration, noise and temperature, and physical work loads (Ilmarinen, 1999). Importantly, workers over 45 years were generally able to determine for themselves when to take breaks and decide on work order, methods and speed of work. The reduced functional capacity with ageing may in part contribute to the finding that the lack of opportunity to ‘self-regulate’ their work is a major factor in early retirement.

Responses to a survey of occupational health and safety officers in the Queensland and New South Wales coal industry indicated that the majority (77%) of responding mines had no specific policies or procedures in place to accommodate older workers (Parker et al., 2004). Rather, there was a general expectation that miners are capable of undertaking most or all duties, irrespective of age. In the minority of mines where such procedures were in place, they were reported as consisting primarily of job reassignment to less physically demanding jobs (83%), redesign of the job (33%) or reassignment of shift (17%).

Greater understanding of the match between workplace demands and the physiological and psychological changes characteristic of the older worker will enable targeted strategies to retain these workers.

1.2.3 Work organisation

In 2000-01, the mining industry had the longest average weekly working hours profile of any industry in Australia, recorded as 45.8 hours (ABS, 2002), with metalliferous miners generally working longer weeks than their colleagues in the coal-mining industry (Heiler et al., 2000).

In recent years, the Australian mining industry has seen an increase in compressed rosters, involving various arrangements of 12-hour shifts (Baker et al., 2003). While the magnitude of the impact may vary, it is clear from the research evidence that shiftwork has negative short and long-term impacts on overall employee health. The interacting and compounding effects of circadian dissociation, poor sleep and social and domestic problems arising from shiftwork in industry are well documented (Folkard, 2003). These factors can significantly contribute to the stress experienced by miners and may reduce the psychophysiological state of the person, such that a higher prevalence of fatigue, reduced levels of well-being and performance decrements become manifest. In the long term, health may also be adversely affected, with individual characteristics such as personality traits, level of physical fitness, age, and commitment to a work schedule playing an important role in the adaptation and tolerance for work outside normal hours. Shift workers tend to have lower work ability than day workers, with this effect more pronounced in older workers (Costa, 2005). Consequently, an increase in the number of older workers will increase the occupational health and safety problems associated with shiftwork unless appropriate interventions are implemented.
Another significant development in the Australian coal-mining industry, particularly in the past decade, has been the decrease in direct employment brought about by the increasing use of outsourced labour (Bowden, 2003). While small, independent, specialist contractors maintain a foothold in the industry, the highly capitalised nature of coal-mining has secured the place of large contracting companies with their own labour forces (Bowden, 2003). This phenomenon has been particularly marked in the past decade. In 1996, fewer than 1000 contractors were employed in the Queensland coal industry. By 2002, this figure had more than tripled to 3081, with contractors representing 33% of the Queensland coal-mining workforce, up from 13% six years earlier (Bowden, 2003).

Waring (2003) argues that the increasing use of contract labour has “enormous repercussions” for occupational health and safety in the industry. The NSW Mines Safety Review 2004 suggests that this phenomenon

...makes it more difficult to assess both aggregate and mine specific trends in injuries etc., especially where their use has been associated with underreporting of incidents. This has, in turn, implications for OH&S management systems and managing return to work (DMR, 2005: 59).

1.2.4 Health of the workforce

Although coal mining generates considerable wealth and creates employment opportunities for Australians, there are significant direct and indirect/human costs involved with extracting coal from the ground. The mining industry has a higher injury incidence rate (89 per 1000 workers) compared to the national average (49.3 per 1000) (ABS, 2002) and a greater number of workers’ compensation claims than any other industry (Parker, 2002; NOHSC, 2002). In addition to these direct costs, there are also indirect, human/emotional costs to workers and their families.

Muscle strength (including lift capacity) and muscle endurance are the individual physical characteristics traditionally considered to have the most prominent effect on musculoskeletal outcomes (Pederson, 2003). Changes in musculoskeletal capacity can be pronounced after the age of 45-50 years. Longitudinal studies have shown that both maximum isometric trunk extension and flexion strength among male workers can decline by 40-50% over a 10-year period (Ilmarinen et al., 1991; Ilmarinen, 1992, cited in Ilmarinen, 2001).

A study of musculoskeletal and cardiovascular capacity among ageing municipal employees over 16 years found reduction in physical capacity over time to be more common among those with high workloads, suggesting that physical workload has more of a wearing than training effect (Savinainen et al., 2004). Declines in muscular strength and endurance occur first in the legs, followed by the trunk, shoulders, arms and then hands (Kawakami & Inoue, 1999). Given the physical demands associated with mining, particularly in the underground
setting, decline in physical strength could play a potential role in injury incidence as well as lost productivity.

Changes in mental functioning are associated with a decrease in precision and the speed of perception, involving the whole body. Sensory and motor functions underlying balance are well known to deteriorate significantly with age. Punakallio (2003) found this deterioration to be similar across the physically demanding occupations of fire-fighting, construction, nursing and home care. When combined with uneven surfaces, and poorly illuminated and hazardous environments, the potential for accidents and injuries involving loss of balance is compounded.

Some studies have shown older workers to have an increased risk of work injury and subsequent disability due to age-associated decrements in physical and cognitive functioning and recuperative ability, but this is not necessarily the case (Pransky et al., 2005b). As Krause et al. (2001) found, duration of disability following workplace injury is affected by a range of other sociodemographic, psychological and attitudinal factors, co-morbidities and job characteristics.

While decrements in many measures of physical and mental capacity occur as a normal consequence of ageing, age-related changes in physiological and mental functioning are highly individual. For example, a 50-year-old worker may have the functional capacity equivalent to the average 25 year-old, or a 45-year-old worker may have the functional capacity equal to the average 80 year-old. This phenomenon indicates the need for workplace strategies focused at the individual level, rather than a ‘one-size-fits-all’ approach.

1.2.4.1 Injury incidence

A high rate of accidents and injuries in mining, relative to other Australian industries, is mirrored in other countries. In the United States, mining has the highest occupational fatality rate (24 per 100,000) of any industry (CDC, 2004). A study of coal miners in the western United States (Madsen et al., 1998) found that two-thirds of current and former miners surveyed had experienced one or more injuries during their mining careers. More than one-third reported suffering current health-related quality-of-life effects, including pain and activity restrictions, from work-related injuries. In a recent study of occupational injury and illness across 313 US industries, coal mining ranked second (after taxicabs) in terms of costs per worker (Leigh et al., 2004).

As the largest coal-exporting nation, the prevalence of workplace injury is of special significance to Australia. A study by the Queensland Injury Surveillance Unit (QISU) found that work-related injuries in coal-mining were twice as likely to require hospital admission as the all-industry average, indicating that coal-mining injuries tend to be more severe (QISU, 1999).

The Lost Time Injury Frequency Rate (LTIFR) is used as an indicator of the extent of injury in the workforce. In mining, the LTIFR is estimated to have fallen to 6 per million hours worked for 2003/04, with declines across all sectors of the
industry. This compares to more than 20 per million hours across the mining industry in 1996/97 (MCA, 2004). This indicator also suggests that some improvement has been made in the coal-mining industry. However, while the LTIFR has decreased over time, the cost of work-related injuries increased to an all-time high in 2001, despite the fact that numbers working in the industry had declined by one-third in the three years prior (Farrar, 2001). Thus, the reliability and validity of this measure has been questioned and it has been suggested that the cost of work-related injuries may be a more realistic measure of safety performance (Farrar, 2001).

In 1991, Leigh et al. reported that 90% of non-fatal lost-time injuries in the NSW coal mining industry occurred in underground coal mines. Sprain and strain injuries accounted for two-thirds of all injury payments, with back injuries and injuries to multiple sites (including the hand, fingers or thumb, knee and ankle) accounting for the largest proportions of total compensation payments. Overexertion as a function of manual handling was a common mechanism of injury. Human factors were cited as the major cause of accident or injury, with only 10% of injuries not involving a human factor. The two most common human causal factors included failure to recognise or rectify a hazard (32%) and the use of incorrect or inappropriate work practices or equipment (24%). Machinery and/or equipment were involved in 64% of all accidents.

Potential contributors to accidents and injuries in coal mining are generated by the work environment itself, the nature of work, work organisational issues and individual factors, including age. There is reasonable evidence to suggest that even if older workers are not at increased risk of injury, their injuries are likely to be more severe (Hull et al., 1996) and they are likely to take longer to recover (Krause et al., 2001; Peele et al., 2005) than their younger colleagues.

The types of accidents that disproportionately affect older workers include falls from heights or machines, slips and trips, and being struck by vehicles, machinery or falling objects. The reduced physical capacity of older people to keep their balance or to move out of the way of hazards is a major factor in such accidents (Parker, 2002). In turn, a range of sensory and motor functions contribute to balance deficits in the older individual (Kerr & Worringham, 2001).

In spite of increased mechanisation in mining, many mining tasks still demand heavy physical work, posing particular difficulties for older workers with reduced functional capacity (Shephard, 1999). Such work exposes these workers to over-exertion injuries and cumulative damage to the musculoskeletal system (de Zwart et al., 1995).

It is evident that workforce demographics should be considered in the assessment and management of injury risk. The age profile of this industry indicates that serious efforts will be required to accommodate an older workforce in a physically demanding environment, while at the same time maximising their contribution in terms of skills and experience.
1.2.4.2 Musculoskeletal disorders

Some coal-mining injuries, such as ligament and muscle strains, are the result of repeated micro-traumas, rather than sudden mishaps, and tend to occur in repetitive tasks such as roof-bolting (Cornelius & Turin, 2001). These conditions develop over weeks, months, sometimes years, usually as a result of an accumulation of damage to musculoskeletal tissues. This occurs as a function of repeated applications of force, often exacerbated by working with awkward postures and exposure to conditions such as vibration (Cornelius & Turin, 2001). Common musculoskeletal disorders (MSDs) of occupational origin of the upper body include carpal tunnel syndrome, tendonitis, hand-arm vibration syndrome, cumulative trauma disorder and repetition strain injury (Gerr et al., 1991).

MSDs constitute the largest category of work-related illness in a number of countries, including the United States, Canada, the United Kingdom, Japan and the Scandinavian nations (Punnett & Wegman, 2004). This is also the case in Australia, where overuse injuries, in which the micro-damage occurring in the musculoskeletal tissues exceeds their normal repair capacity, continue to constitute the largest category of work-related injuries in mining (Donoghue, 2004). Risk factors for this cumulative type of injury common to mining include prolonged and awkward postures, forceful exertion, heavy or frequent lifting, forceful gripping, repetitive motions, jolting or jarring, vibration exposure and contact stress (Wiehagen & Turin, 2004).

The cumulative nature of musculoskeletal disorders such as sprain and strain injuries suggest that older miners may be more at risk, due to potentially more years of exposure to the physically demanding tasks associated with coal mining (Wiehagen & Turin, 2004). Long and arduous working conditions have been linked to an accelerated ageing process, and it is widely recognised that occupational strain injuries contribute to the development of joint diseases (Calmels et al., 1998). Older workers with MSDs have been shown to incur significantly more lost work days and wage replacement costs than younger workers with similar conditions (Peele et al., 2005). Heavy physical work has been associated with an increased risk (OR = 2.21) of early retirement due to musculoskeletal disorders (Karpansalo et al., 2002).

Underground mining is considered one of the high-risk industries for work-related MSD (Gerr et al., 1991). In the UK, mining in general accounts for the highest rate of annual reported MSD collected by the Musculoskeletal Occupational Surveillance Scheme (MOSS) (Cherry et al., 2001). In the US, back injuries account for the greatest number of lost work days in mining due to injury (NIOSH, 2002). A retrospective study of retired miners in France found significant associations between the length of time spent working at the coal face, locomotion impairment of the lower back, occupational strain and functional independence (Calmels et al., 1998). The repercussions of occupational strain associated with mining continued to affect the quality of life of these workers into retirement.
When tasks must be carried out rapidly, as can occur to meet critical production targets or complete urgent maintenance, such effects can be exacerbated. A study of US marines found that workload time pressure was associated with both upper extremity symptoms and low back pain, while higher biomechanical exposures increased the risk of concurrent upper extremity and low back symptoms (Huang et al., 2003). The literature on lower extremity MSDs, by comparison, is relatively sparse (D’Souza et al., 2005).

A major review of the epidemiological evidence of work-related MSDs found that manual material handling and whole-body vibration were the major physical stressors related to back disorders, while segmental vibration and repetitive motion were the major factors for upper-extremity disorders (Punnett & Wegman, 2004). Certain psychosocial factors, such as high job demands, low decision latitude and few rest breaks were also shown to be strong indicators. The risk of MSD is more pronounced when a combination of factors is present in the workplace. These reviewers concluded that an international near-consensus exists suggesting a causal relationship between ergonomic risk factors such as repetitive motion, forceful exertion, awkward postures and vibration, and the development of work-related MSDs, many of which are preventable if protective action is instigated (Punnett & Wegman, 2004).

Musculoskeletal disorders and cumulative trauma disorders, common in physically demanding work such as mining, can lead to chronic and sometimes disabling pain, which in turn causes activity restrictions and reduced functional capacity (Saastamoinen et al., 2005). The prevention and management of these disorders before they reach disabling dimensions could help to maintain work ability and prevent long-term absences or premature retirement.

1.2.4.3 Cardiovascular conditions

The influence of lifestyle factors and socioeconomic determinants of health can be exacerbated by workplace exposures. A body of research literature is emerging on the relationship between work factors and cardiovascular health. Work-related cardiovascular disease in the United States has been estimated to cost US$10 billion to US$20 billion per year (Leigh & Schnall, 2000; cited in Wegman & McGee, 2004).

A large retrospective Finnish study of the role of work in cardiovascular mortality over 20 years found that exposure to diesel exhaust, high workload, noise and irregular working hours (all factors of coal mining) increased the risk of cardiovascular disease and myocardial infarction (Virtanen & Notkola, 2002). Death from myocardial infarction was strongly affected by workload, lack of job control and noise, whereas cerebrovascular mortality was more influenced by shiftwork, followed by lack of control and diesel exhaust. The statistical models used suggested that the elimination of unfavourable working conditions might have reduced the number of cardiovascular deaths by 8%, myocardial infarctions by 10% and cerebrovascular deaths by 18%.
Recent studies report that shift workers suffer a 50% higher incidence of coronary heart disease and an increased risk of myocardial infarction compared to those working regular hours (Knutsson et al., 1999; Knutsson, 2003 cited by Rogers & Grunstein, 2005). A review of the research literature on the relationship between shift work and risk factors for cardiovascular disease found that on balance, shift workers had a 40% increased risk related to disruption of circadian rhythms, disturbed socio-temporal patterns, stress behaviours (smoking, diet, alcohol, exercise) and biochemical changes (cholesterol, triglycerides) (Boggild & Knutsson, 1999).

The results of a recent Korean study suggest an association between shift work duration and the metabolic risk factors of cardiovascular disease (Ha & Park, 2005). In Japan, shift work has been associated with increases in body mass index (BMI) and waist to hip ratio (WHR), both identified as risk factors for cardiovascular disorder (Ishizaki et al., 2004). A study of shiftworkers in their 50s at a Japanese pulp and paper mill found a positive association between job type and hypertension, suggesting that different job types should not be examined together when examining the effects of shiftwork on blood pressure (Inoue et al., 2004).

Yao et al. (2003) examined the interaction of occupational stress factors with cardiovascular function in different vocational populations. Results showed that blood pressure was higher in older workers, with job control, job demands, job responsibility, role in job, and shift work the main stress factors affecting systolic and diastolic blood pressure. Job conflict, less opportunity for participation in decision making and severe job loads were the major occupational risk factors for primary hypertension.

Work and task factors, together with environmental factors, were also implicated in cardiovascular health in a study of Russian underground coal miners, in which it was found that 63% of unexpected deaths were related to cardiac events associated with hard strenuous work and hot working conditions (Cherkasov, 2000).

Australian coal miners have been reported to have higher levels of hypertension and obesity (both risk factors for heart disease) than the general population (Bofinger & Ham, 2002). In the 1970s, the Coalfields district of NSW was identified as having one of the highest rates of death from coronary heart disease (CHD) in Australia (Higginbotham et al., 1999). Levels of overweight and obesity in this sub-population were shown to largely parallel the pattern of heart disease mortality (Alexander et al., 1986).
1.2.4.4 Mental disorders

Five of the 10 leading causes of disability worldwide are mental health problems (WHO/ILO, 2000). Even so, the importance of psychological well-being and mental health in the workplace is generally underestimated and seldom included in studies of occupational health.

In the UK, stress, depression and anxiety are the most common occupational health problems after musculoskeletal disorders (HSE, 2003). The Department of Health and the Confederation of British Industry estimate 15 to 30% of workers will experience some form of mental health problem during their working lives (WHO/ILO, 2000). Annually in the UK, 80 million work days are lost due to mental illnesses, costing employers £1-2 billion each year (WHO/ILO, 2000).

Workers with depression or anxiety are reported to be 1.5 times more likely to suffer from work-related musculoskeletal disorders, to take twice the amount of sick leave than the general working population, and to report a much greater effort required to function at work (Glozier, 2002).

In the United States, an estimated 2000 million work days are lost each year due to depression alone (WHO/ILO, 2000). Even in Finland, a country with a highly advanced occupational health system, mental health problems are now the most common reason for sick leave and disability pensions (Liimatainen, 2000).

A systematic review of the literature on work-related psychological ill-health (Michie & Williams, 2003) found that the most strongly associated work factors were work demands (long hours, workload and work pressure), lack of job control and poor support from managers. The reviewers suggest that increased participation in decision-making and problem solving, and improved workplace communication can potentially improve levels of psychological health and reduce sickness absences (Michie & Williams, 2003).

Haslam et al. (2005) studied the effects of anxiety and depression on job performance and workplace safety in the UK. The study found that the physical and psychological symptoms of these conditions were related to impairment of work performance and increased risk of accidents. Unreasonable workloads were perceived by workers as contributing to anxiety and depression (Haslam et al., 2005).

A cross-national study of the relationship between psychosocial job factors and depression in more than 1000 workers aged 45 to 65 found an association between effort-reward imbalance and depression, which remained strong after controlling for demographic and socioeconomic factors (Pickhart et al., 2004). The authors suggest that, in future, depression may prove to be a link between the psychosocial work environment and the development of chronic diseases.
**1.2.4.5 Sleep problems**

Insufficient sleep and impaired alertness are common problems of irregular working hours (Ohayon et al., 2002; Sallinen et al., 2005). A phenomenon described as “shift work sleep disorder” is used to describe the insomnia and excessive sleepiness related to non-regular work schedules (Rogers & Grunstein, 2005). Disturbed sleep patterns, such as those associated with shift work, are a strong predictor of fatigue, which is exacerbated by age, high work demands and physical effort at work (Akerstedt et al., 2002a and b; 2004).

The study of the effects of various shift and roster patterns on sleep disorders is a highly complex issue, but workers on night shift or rotating shifts have been shown to have a higher incidence of sleep disorders than those on day shift (Ohayon et al., 2002). Ilmarinen (1999) cites an Austrian study which showed that WAI scores were lower for shift workers than day workers at a chemical company. Another Austrian study, of bus drivers, found that the tiredness and sleep disorders associated with shift work were strongly correlated with work ability (Kloimuller et al., 2000).

Sleep problems tend to be more common in older people in general, particularly ageing shift workers (Akerstedt, 2002a; Costa, 2005). A Swedish longitudinal study that monitored 58,115 workers at regular intervals over 20 years identified age >49, physically strenuous work and shift work among the significant predictors of sleep disorders (Akerstedt et al., 2002b).

The nature of work in mining requires the maintenance of high levels of alertness which presents significant challenges if the workforce is suffering from sleep disturbances, sleep deprivation and sleep disorders. Inadequate sleep contributes to fatigue, which results in loss of alertness (Parker et al., 2004). More than half the OHS officers in New South Wales and Queensland coal mines surveyed by Parker et al. (2004) indicated that fatigue was affecting work performance in their workplace.

**1.2.5 Occupational exposures and worker health**

Estimating a worker’s occupational exposure to risk factors for injuries or diseases is difficult. Commonly exposure assessment consists of documenting the occupational history of subjects, and estimating the frequency, intensity and duration of exposure (Burstyn & Kromhout, 2002). Methodologically, retrospective exposure assessment is extremely challenging and is often limited by the lack of longitudinal information. Palmer et al. (2000) sought to determine the validity of self-reported occupational exposure to whole-body and hand-transmitted vibration through observation, examination of tools and machinery, and interviews with managers and supervisors. The results suggested that the accuracy of self-reported recent exposures was generally high, but the actual duration of exposure tended to be overestimated. A Swedish study (Koster et al., 1999) found that recall of past occupational exposure is influenced by the worker’s current exposure status.
Various strategies, methods and tools have been developed to deal with exposure measurement in occupational studies. Calmels et al. (1998), in a study of occupational strain among French miners, developed an exposure rating system by assigning coefficients to length of time worked, physical effort, atmospheric factors and other exposures (such as noise and chemicals).

It has been argued that improved exposure assessment is necessary; for example, in order to examine the causal pathway between workplace factors and the development of MSDs (D’Souza et al., 2005).

The assessment of exposure levels is necessarily limited in cross-sectional studies, especially for physical variables that are hard to measure even in optimal laboratory conditions. In Survey 2 of the current study, however, data were collected on self-reported frequency, intensity and duration of exposure to a number of physical, environmental and organisational factors. A simple formula was developed in order to calculate an exposure value for each of these factors. While not definitive, these may provide a basis for selecting factors for which exposure measures are of importance and require further development.

1.2.6 Work ability

Objective assessment of work ability (for either individual workers or groups) may be difficult due to time limitations, costs, logistics or lack of validated methods (de Zwart et al., 2002). Evaluation of work ability is complex and requires a multifactorial approach. This precludes reliance on the use of objective assessments only, such as medical/physical examinations, and it has been suggested that any evaluation should incorporate workers’ subjective estimations of their personal resources in relation to work demands (Ilmarinen et al., 1997).

To this end, the Work Ability Index (WAI) was developed by the Finnish Institute of Occupational Health (FIOH) in 1981 for use in a longitudinal study of the work ability of more than 6500 ageing municipal workers (Ilmarinen et al., 1991). A self-administered questionnaire, the WAI allows for the calculation of an index of work ability by summing the scores of seven items, each evaluated by one or more questions (discussed in more detail in the Methods section) (Ilmarinen & Tuomi, 1993; Tuomi et al., 1994).

The Finnish longitudinal study found that work ability in municipal workers declined on average 6 points over 11 years, from 40 (good) to 34 points (moderate), with the rate of decline increasing according to the physical demands of work, and with ageing (Ilmarinen et al., 1997). At the mean age of 58 years, men in physically demanding jobs were twice as likely to have a poor Index score than those performing non-physical work. The Finnish studies found that low scores on the WAI and heavy physical workload were associated with early retirement (Tuomi et al., 1997; Ilmarinen, 1997; Salonen et al., 2003). A marked decline in work ability from the age of 50 was also observed among construction workers, with low scores shown to be highly predictive of disability pensions (Liira et al., 2000).
The Index has been adopted in a variety of geographical and occupational settings, translated into more than 20 languages (Simon, 2005) and administered by varying means. Because its measures are relative (workers estimate their current work ability against lifetime best) and general (in that they are not based upon specific work tasks), the Index can be used across industries and among heterogeneous working populations. This represents a strength of the Index, allowing broad application and comparisons, but also a potential limitation, since issues specific to an industry are not included. For this reason, supplementary questions, as used in the current study, are invaluable.

Studies among industrial workers are particularly relevant to this report. Around the world, the WAI has been administered to German transport drivers (Karazman et al., 1999), Austrian bus drivers (Kloimuller et al., 2000), metallurgical plant workers in Poland (Makowiec-Dabrowska et al., 2000), Estonian industrial workers (Vilkis & Kahn, 2000), Dutch construction workers (de Zwart et al., 2002), Belgian firefighters (Kiss et al., 2002) and Italian railway construction workers (Capanni et al., 2005). Add to the list steel factory workers in Japan (Suzuki et al., 2004) and Brazilian industrial workers (Walsh et al., 2004) and the versatility of the Index is apparent.

Studies of similar occupations in comparable settings have yielded similar WAI scores. For example, bus drivers of similar ages in Germany and Austria scored an average 37 and 36.8 respectively (Karazman et al., 1999; Kloimuller et al., 2000). On the other hand, WAI scores for nurses in Brazil (42), Europe (39.1) and China (32.5) varied considerably, probably reflecting the different cultures and working conditions of the study populations (Duran & Cocco, 2004; Camerino et al., 2003; Yang et al., 2004a).

Since its development, the WAI continues to be utilised in its home country for studies of various occupations, including vehicle inspectors (Miettinen & Louhevaara, 1994), construction workers (Liira et al., 2000), women in physically demanding jobs such as home care nursing (Nurminen et al., 2002; Pohjonen & Ranta, 2001), municipal workers (Aittomaki et al., 2003), ageing food industry workers (Salonen et al., 2003; Nygard et al., 2005), firefighters (Punikallio et al., 2004), metal workers (Tuomi et al., 2004) and professional cleaners (Hopsu et al., 2005).

A growing number of studies, regardless of the setting, have confirmed the association between ageing and work ability (Nielsen 1999; Reiso et al., 2001; Kiss et al., 2002; Yang et al., 2003; De Boer et al., 2004; Yang et al., 2004b), particularly in physically demanding jobs (Louhevaara et al., 1999; Liira et al., 2000; Aittomaki et al., 2003; Salonen et al., 2003).

The WAI questionnaire has been found to be a reliable data collection instrument (de Zwart et al., 2002), suitable for both the description and prediction of work ability for ageing workers and those undertaking physically demanding tasks (Liira et al., 2000). The Index has proved to be a practical tool for the assessment of workers’ fitness for duty, as well as a predictor of future disability (Ilmarinen & Costa, 2000). It has been suggested for use as a means of matching
workers to appropriate jobs, as well as for monitoring functional capacity over time (Chan et al., 2000; Savinainen et al., 2004). The effects of workplace interventions, such as the modification of physical work demands or the enhancement of the physical fitness of employees, have been evaluated through application of the WAI (Karazman et al., 1999, 2000; Liira et al., 2000).

In addition, the value of participation in physical activity programs designed to enhance or maintain functional capacity has been studied in the context of work ability. One Finnish study concluded that workplace physical exercise programs can help prevent decline in work ability, suggesting that preventive measures, especially for those involved in physically demanding work, should begin before the onset of age-related deterioration of health and physical activity (Pohjonen & Ranta, 2001). In this particular study, WAI was measured 3 times over 5 years, declining 3 times faster in the control or non-exercise group.

The reliability and credibility of the Work Ability Index is such that a WAI network has been established in Germany with the overall aim of promoting the instrument (WAI Netzwerk, 2004; Hasselhorn et al., 2005a). This initiative includes the development of a national WAI database, downloadable software for data entry and data analysis based on national reference values, in order to enable the comparative presentation of results across studies and industries (Hasselhorn et al., 2005b).

In other developments, the WAI is being used as an integral data collection and measurement tool in a major 10-nation collaborative research project financed by the European Commission, and investigating premature departure from the nursing profession in Europe. This is a workforce that shares with the contemporary Australian coal-mining industry challenges of skill shortages, insufficient new recruits, and insufficient retention (NEXT, 2005).

Promotion of work ability and adjustment of physical workload among older workers have been recommended as important factors in reducing premature departure from the workforce (Salonen et al., 2003). Perceived work demands tend to increase with age, therefore these demands need to be balanced according to the capacity of the ageing worker (Nygard et al., 1997). Maintenance of a ‘good’ work ability score and sustained interest in work have been suggested as essential for keeping older workers in the workforce (Karazman et al., 2000).

The results of the various follow-up studies in the Finn Age project (e.g. Ilmarinen et al., 1997; Ilmarinen & Costa, 2000; Ilmarinen 2001) have been used to inform workplace health promotion strategies and organisational practices to enhance the work ability and well-being of older workers (Ilmarinen & Rantanen, 1999; Tuomi et al., 2001; Ilmarinen, 2004; Tuomi et al., 2004). According to the concept of the work ability, health promotion during ageing suggests that:

... it is not only possible to obtain good work ability and health, but also a high quality of work and production, a high quality of life and well-being, and an active and meaningful retirement (Tuomi et al., 2001).
This review has summarised research on the health problems and challenges facing older miners at work, whether in terms of workload, tasks, rosters, equipment or environment. It is also acknowledged however, that many older miners make disproportionately large contributions by application of their knowledge and experience. Preserving the health and work ability of older miners brings significant benefits to the industry, but it is also central to the prospect of a healthy, active, and fulfilling retirement.
1.3 STUDY OBJECTIVES

A major goal of the research was to determine the work ability of a cross-section of the Australian coal-mining workforce and to determine those health and organisational factors which influence work ability. Any differences in work ability with respect to age, type of mining operation (open-cut and underground mining operations), and different work categories were also investigated. An additional goal was to identify the organisational, environmental, cultural and behavioural factors which characterise older miners with a record of injury as distinct from those who are injury free.

Specifically the study aimed to:

\(d)\) Determine the match between work demands and work ability in Australian coal mine employees of different ages;

\(e)\) Determine any differences in medically related factors that may impact on work ability and in relation to type of operation and occupational category; and

\(f)\) Characterise those older miners who have high levels of work ability and low rates of injury, in terms of work history, individual attributes and work patterns.

The results of the study will increase knowledge of the work ability status of workers in the Australian coal-mining industry, and factors which affect this measure. Such knowledge will provide a baseline for further research concerned with the older worker, and identify priority areas for interventions designed to better accommodate this segment of the workforce. The study will contribute to the evidence base for the development of policy and procedures to enable those older workers who wish to stay in the workforce to continue working safely, and without detriment to their short and longer term health.
SECTION 2  METHODS

 Educação

 Study design
 Study instrument
 Preparation for survey
 Sampling procedures
 Data collection
 Sample and response details
 Data management
 Study factors, measures and data analysis
 Strengths and limitations of the study
2.1 STUDY DESIGN

This study used a cross-sectional survey design. The survey was conducted in two parts and utilised a modified version of the Work Ability Index (Tuomi et al., 1994), together with supplementary questions on industry-specific work tasks and work demands. An initial larger survey was replicated and administered to a smaller population of miners, with the inclusion of more specific questions focussing on the relationship between work ability and history of exposure to a range of risk factors for injury across working life in the coal-mining industry.

The survey instrument has been used successfully in other industries overseas and was utilised in this study to characterise work ability in open-cut and underground coal miners in Queensland and New South Wales. This study builds on the research team’s work on the physical demands of underground mining and injury prevention practices in the Industry.

2.2 STUDY INSTRUMENT

The survey instrument developed for this study incorporates the Work Ability Index (WAI), a well-validated self-report questionnaire developed by the Finnish Institute of Occupational Health from baseline data collected on some 6500 employees in different occupations (Ilmarinen et al., 1993; Tuomi et al., 1994).

To the best of our knowledge, this study represents the first time the Work Ability Index has been administered either in Australia or in coal-mining. The only other mining-related study identified from the literature which used the WAI involved Polish workers at a metallurgical plant (Makowiec-Dabrowska et al., 2000).

Some terminology, including medical terms, was modified to suit Australian conditions and to fit the background and orientation of the participant group. These modifications were made in teleconference consultation with Professor Juhani Ilmarinen, Director of the Finnish Institute of Occupational Health and one of the original architects of the Work Ability Index, to ensure the validity of the Index was not compromised.

Instructions and project information were contained on the cover sheet of the survey. This included the organisations involved in the study, the aims of the project, confidentiality information, ethical approval and contact details.

2.2.1 Survey 1

The survey instrument was piloted in order to estimate the time it would take to complete and to check the appropriateness of the industry-specific questions. In September/October 2004, the questionnaire was completed by a number of staff of the Queensland University of Technology (QUT), a small number of members of the general public with different employment status and people with knowledge of the mining industry. The considerable research experience and
knowledge of the coal-mining industry within the research team and input from coal-mining industry representatives enabled the development of industry-specific questions for inclusion in the survey. Following feedback from mining professionals, the questionnaire was modified in areas related to work location, job description/occupation and major duties.

The Work Ability Index (WAI) score is determined from the answers to a series of questions regarding the worker’s personal resources to meet the physical and mental demands of their job, as well as the worker’s health status. The questions are included in the following seven ‘items’:

1. Current work ability compared to lifetime best;
2. Current work ability in relation both to the physical and mental demands of work;
3. Number of diagnosed diseases;
4. Subjective estimation of work impairment due to disease;
5. Sickness absence during the past year;
6. Own prognosis of work ability after two years; and
7. Mental resources.

Each item includes one or more questions relating to a particular aspect of work and health. Points are scored according to responses, with absence of disease or injury scoring more points than presence of disease or injury, for example. Some items are weighted according to whether the work is primarily physically or mentally demanding. For example, the multiplier used for the work ability in relation to the demands of the job item is higher for physical demands when the work is primarily physically demanding, and higher for mental demands when the work is primarily mentally demanding.

The first item on the WAI index measures subjective work ability by asking the respondents to rate their own estimate of current work ability against their lifetime best on a scale of 0 (currently unable to work) to 10 (work ability at its best). The creators of the WAI found that the predictive power of the index was highest for this item.

Workers were also asked to indicate the number of diseases or injuries they currently have according to their own opinion, as well as those diagnosed by a doctor. The categories of medical condition analysed in this report are listed below in Table 2.1.
### TABLE 2.1  Key medical conditions included in the survey

<table>
<thead>
<tr>
<th>DETAILS OF MEDICAL CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injury from accident</td>
</tr>
<tr>
<td>• Back</td>
</tr>
<tr>
<td>• Leg/foot</td>
</tr>
<tr>
<td>• Arm/hand</td>
</tr>
<tr>
<td>• Other part of body</td>
</tr>
<tr>
<td>Musculoskeletal disorders</td>
</tr>
<tr>
<td>• Conditions of the upper back or cervical spine</td>
</tr>
<tr>
<td>• Conditions of the lower back</td>
</tr>
<tr>
<td>• Sciatica: pain radiating from the back into the leg</td>
</tr>
<tr>
<td>• Musculoskeletal disorder affecting the arms, legs, hands or feet</td>
</tr>
<tr>
<td>• Arthritis</td>
</tr>
<tr>
<td>• Other musculoskeletal disorder</td>
</tr>
<tr>
<td>Cardiovascular conditions</td>
</tr>
<tr>
<td>• Hypertension (high blood pressure)</td>
</tr>
<tr>
<td>• Coronary heart disease; chest pains during exercise (angina pectoris)</td>
</tr>
<tr>
<td>• Coronary thrombosis; myocardial infarction (heart attack)</td>
</tr>
<tr>
<td>• Cardiac insufficiency (heart failure)</td>
</tr>
<tr>
<td>• Other cardiovascular condition</td>
</tr>
<tr>
<td>Mental conditions</td>
</tr>
<tr>
<td>• Mental disorders or severe mental health problem (e.g. severe depression, mental disturbance)</td>
</tr>
<tr>
<td>• Slight mental disorder or problem (e.g. slight depression, tension, anxiety, mood changes)</td>
</tr>
<tr>
<td>Sleep problems</td>
</tr>
<tr>
<td>• Insomnia</td>
</tr>
<tr>
<td>• Sleep apnoea</td>
</tr>
</tbody>
</table>

Other conditions included in the Index are respiratory conditions, neurological and sensory conditions, digestive conditions, genitourinary conditions, skin conditions, tumours, endocrine and metabolic conditions, blood conditions, birth defects and other conditions or disorders. Only those conditions reported as being diagnosed by a doctor are used to calculate the Index score.

The medical conditions listed in this study were restricted to those included in the Work Ability Index, with the exception of insomnia and sleep apnoea. The original Index does not include a specific category for sleep disorders. Due to the recent increase in compressed rosters in the mining industry (Baker et al., 2003) and evidence of poor sleep arising from shiftwork (Folkard, 2003) these additional conditions were included in this study. The additions make an inconsequential difference in the overall calculation of the WAI, yet provide specific information that may be relevant to the industry and may otherwise not have been captured.

Other industry-specific diseases such as silicosis or coal worker’s pneumoconiosis (CWP) were not individually listed under medical conditions, however, respiratory conditions is a category in the index. Within each category of medical condition, respondents also have an option to list other conditions or disorders.

The WAI also measures estimated work impairment due to medical conditions. Respondents were asked to estimate the effects of any medical condition on their ability to perform their work. Points for this item are measured on a six-point scale, from 1 = fully impaired to 6 = no impairment.
The overall WAI score is derived from the sum of the seven items on the questionnaire. Possible scores range from a minimum of 7 to a maximum of 49.

To facilitate interpretation of the WAI relative to the mining industry, supplementary questions provided information on mine type and section (e.g. production, development, preparation plant, office), length of time in the industry, length of time in current position, primary job description, major duties, job tasks, primary shift/roster, how often workers felt mentally and physically tired at the end of a regular shift and roster, and their employment status.

Respondents were asked to nominate their primary job description, as listed in the following table.

**TABLE 2.2 List of primary job categories by mine type**

<table>
<thead>
<tr>
<th>UNDERGROUND</th>
<th>OPEN CUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operator-Maintainer/Mine worker</td>
<td>Operator-Maintainer/Mine worker</td>
</tr>
<tr>
<td>Deputy/Supervisor</td>
<td>Deputy/Supervisor</td>
</tr>
<tr>
<td>Fitter</td>
<td>Fitter</td>
</tr>
<tr>
<td>Mechanic</td>
<td>Mechanic</td>
</tr>
<tr>
<td>Electrician</td>
<td>Electrician</td>
</tr>
<tr>
<td>Beltman</td>
<td>Beltman</td>
</tr>
<tr>
<td>Driller</td>
<td></td>
</tr>
<tr>
<td>Professional/Administration</td>
<td>Professional/Administration</td>
</tr>
<tr>
<td>Other</td>
<td>Other</td>
</tr>
</tbody>
</table>

Instructions were given to *tick the box that best describes* the worker’s job/occupation. Some respondents ticked more than one box. For the purposes of data analysis, the following decisions were made:

- If Deputy/Supervisor was selected, plus another position, Deputy/Supervisor was the default.
- If a Trade was chosen, plus another job (other than Deputy/Supervisor), the trade was the default.
- “Other” was not included in the analysis.

On examination of responses, it became apparent that a number of job categories could be collapsed, for example, mechanics and fitters, who carry out similar tasks. Drillers and beltmens were included in the Operator-Maintainer/Mine Worker category. The collapsed job categories used for both mine types in the final analysis were:

- Operator-Maintainer/Mine worker
- Deputy/Supervisor
- Mechanic/Fitter
- Electrician
- Professional/Administration
Respondents were also asked to select their major work duties from a list of underground and open-cut duties compiled in consultation with coal-mining industry professionals. In addition, they were asked how frequently particular work tasks were performed on a Likert-type scale (Never, Seldom, Sometimes, Often or Very Often).

The final question asked respondents to:

> List the three most important things they believed would help older miners continue working safely and productively as long as they wish.

This was the only open-ended question included in Survey 1.

2.2.2 Survey 2

Based on the findings from the initial survey (Survey 1), a second survey instrument was developed in order to elicit further detail from respondents. Survey 2 contained all the components of the original survey (Survey 1) as well as further questions designed to explore the relationship between work ability and history of injury with the aim of identifying those work organisation, work environment and individual health-related factors that are associated with injury and differing levels of work ability.

Survey 2 collected data on a number of factors relating to the respondents’ work history and experience of workplace injury. Many of these questions used a visual analogue scale (50mm horizontal line with verbal or numerical “anchors”) on which the respondent placed a vertical mark to indicate their rating of the proportion of time, the level of importance attached to particular factors, or the extent to which they agreed with particular statements. The questions focussed on the entire working career and the extent to which the worker felt certain factors had promoted work ability and protected them from injury or contributed to injury.

Table 2.3 outlines the major section headings of Survey 2’s supplementary questions, including examples of questions and how responses were measured.
**TABLE 2.3** Summary of supplementary questions used in Survey 2

<table>
<thead>
<tr>
<th>Section heading</th>
<th>Examples</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>WORKPLACE BACKGROUND</td>
<td>Questions about work history, including:</td>
<td>Not at all → Extreme</td>
</tr>
<tr>
<td></td>
<td>▪ how physically demanding work has been;</td>
<td>▪ e.g. underground, maintenance</td>
</tr>
<tr>
<td></td>
<td>▪ main mine type and job location;</td>
<td>▪ yes/no</td>
</tr>
<tr>
<td></td>
<td>▪ whether (and for how long) employed in another industry</td>
<td>▪ years/months</td>
</tr>
<tr>
<td>WORKPLACE INJURY</td>
<td>Includes questions about most recent and most serious injury, body part/s injured, and the effects of injury on the worker.</td>
<td>0% → 100%</td>
</tr>
<tr>
<td></td>
<td>Proportion of working life injury-free?</td>
<td>Much less → much more</td>
</tr>
<tr>
<td></td>
<td>How injury-prone compared to other workers in the same job?</td>
<td></td>
</tr>
<tr>
<td>SHIFT PATTERNS</td>
<td>Average working hours over entire career in coal mining.</td>
<td>0% → 100%</td>
</tr>
<tr>
<td></td>
<td>The proportion of time spent working different shift patterns and roster types.</td>
<td></td>
</tr>
<tr>
<td>WORK DEMANDS</td>
<td>Physical demands of various work activities in terms of:</td>
<td>0% → 100</td>
</tr>
<tr>
<td></td>
<td>▪ duration</td>
<td>Low → Extreme</td>
</tr>
<tr>
<td></td>
<td>▪ frequency</td>
<td></td>
</tr>
<tr>
<td></td>
<td>▪ intensity</td>
<td></td>
</tr>
<tr>
<td>WORK ORGANISATION &amp; CULTURE</td>
<td>How often respondent has experienced particular factors of work organisation and culture across their working career</td>
<td>Never → Always</td>
</tr>
<tr>
<td></td>
<td>How important these factors have been in terms of preventing injury and promoting work ability</td>
<td>Not important → Extremely important</td>
</tr>
<tr>
<td>WORK ENVIRONMENT &amp; PHYSICAL FACTORS</td>
<td>How often the worker has experienced factors of work environment and physical demands, e.g. excessive heat, poor visibility, uneven ground.</td>
<td>Never → Always</td>
</tr>
<tr>
<td></td>
<td>Perceived effectiveness of current controls in protecting workers from these factors and promoting work ability.</td>
<td>Completely effective → Completely ineffective</td>
</tr>
<tr>
<td>WORK &amp; HEALTH</td>
<td>The extent to which the worker has experienced a number of health-related factors, e.g. mentally stressful situations, sufficient fluids, adequate sleep.</td>
<td>Never → Always</td>
</tr>
<tr>
<td></td>
<td>The level of agreement with statements pertaining to these factors</td>
<td>Disagree → Agree</td>
</tr>
</tbody>
</table>
The supplementary section of Survey 2 concludes with an open-ended question:

*List in order the 3 most important factors you believe contribute to avoiding injury in the workplace.*

### 2.3 PREPARATION FOR SURVEY

A major research goal was to define a survey sample which was representative of the NSW and Queensland coal-mining workforce, with participation across the different categories of work involved in underground and open-cut operations.

To optimise participation or response rates, an extensive communication campaign was implemented across the potential participating mines and key industry groups prior to administration of the survey. This included presentation at State Health and Safety Conferences, consultation with operator and union representatives and presentations to OH&S professionals and worker groups at individual mine sites.

Representatives of the Construction Forestry Mining and Energy Union (CFMEU) greatly assisted in the communication of the aims of this project at state and local levels.

The research team liaised with mine management, senior site executives, occupational health and safety officers, operations managers, deputies/supervisors, and individual workers. This face-to-face communication strategy was supplemented by written materials, including circulation of a 3-page project description aimed at union representatives, mine managers and OH&S managers, as well as a one-page flyer, targeting all mine workers, displayed in poster form on notice boards and in crib rooms.

The communication process resulted in endorsement of the research project by both union and management groups, as well as increased awareness among the mining workforce of the purpose and nature of the research, and an exceptional level of participation.

ACARP provided two industry mentors who constituted an advisory group to the project. Project progress meetings with this group gave the research team opportunity to present project updates and receive advice on industry matters relating to the project.

### 2.4 SAMPLING PROCEDURES

Mine sites in QLD and NSW, both open-cut and underground, of differing size and of varying company ownership were invited to participate in the study. These sites included workers considered to be permanent and contractors.

A figure of 1500 mine workers was chosen as the target sample size. This figure represented approximately 10% of the QLD and NSW coal-mining workforce at the
time of the research design. Another target established that at least 25% of the sample was to include workers over the age of 45 years.

2.5 DATA COLLECTION

All procedures were undertaken in accordance with National Health and Medical Research Council (NHMRC) guidelines for ethical conduct in research practice and with the approval of the Queensland University of Technology Human Research Ethics Committee. Participation was voluntary and all surveys were completed anonymously and confidentially.

Survey 1 was administered to 1624 permanent employees and contract workers at 16 mine sites in the Bowen Basin (QLD) and Hunter Valley (NSW), between November 2004 and February 2005. Administration of the survey instrument was conducted on each occasion by the same researcher, thus ensuring a consistent approach across the participating mines.

Survey 2 was administered to a smaller sample of workers (178) (Sample 2), both permanent employees and contractors, with a comparable representation of workers in different work categories and ages as in the larger sample. This survey was administered during June and July 2005 to mine sites in the Bowen Basin (QLD) and Hunter Valley (NSW).

Survey data were collected on site at pre-arranged times according to production and other workplace demands. Deputies and supervisors on duty were informed of the project and often assisted with the coordination of crew members to complete the questionnaire. On most occasions, the questionnaire was completed by groups of workers during pre-shift meetings, safety and toolbox meetings, crib breaks, and occasionally to individuals (such as administrative staff) at a convenient time during the working day.

Prior to completion of the survey, the research team member introduced herself and asked the workers to note the information contained on the first sheet of the survey. The information was discussed with the workers in order to emphasise the institutions involved in the project, the project objectives and issues of confidentiality and anonymity. The workers were asked to complete the survey under quiet conditions and with respect for personal confidentiality. Essential survey instructions were provided, and any queries were answered by the research team member.

The mine workers were reassured that no data collected from individuals would be seen by their employers. Nor would the aggregate data for particular mine sites be made available to mining companies or mine site managers or be identified in the report. These conditions were agreed to in consultative meetings with union representatives and the ACARP mentors. Surveys were completed anonymously and particular attention to these issues of confidentiality provided some confidence in the validity of the responses.
2.6 SAMPLE AND RESPONSE DETAILS

2.6.1 Study samples

Study sample 1 comprised 1624 predominantly male (94%), full-time (96%) workers, representing 7% of the total NSW and QLD coal mining workforce (ABS, 2004). In 2001, NSW and QLD accounted for over 95 per cent of employment in the Australian black coal industry (ACA, 2005).

The total coal-mining workforce across the two states was 23,138 (9946 in NSW; 13,192 in QLD) at the time of the study (Coal Services, 2005; NRM, 2004). Table 2.4 shows numbers of coal-mining employees by state and type of mining operation.1

<table>
<thead>
<tr>
<th></th>
<th>NSW (31 Dec 2004)</th>
<th>QLD (30 Jun 2004)</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underground</td>
<td>4904</td>
<td>3202</td>
<td>8106</td>
</tr>
<tr>
<td>Open-cut</td>
<td>5042</td>
<td>9990</td>
<td>15,032</td>
</tr>
<tr>
<td>TOTAL</td>
<td>9946</td>
<td>13,192</td>
<td>23,138</td>
</tr>
</tbody>
</table>

The mean age of survey respondents was 39.9 years, with 50.3% over the age of 40, and one-third in the 40-49 years age bracket. Mackay (2003) reported the average age of Australian mining employees as 39. According to Coal Services (2005), the average age of the NSW coal industry workforce in 2003 was 43.5 (44.1 underground; 42.8 open-cut), suggesting the coal-mining sector has a slightly older workforce than metalliferous mining. Comparative figures were not available for the Queensland coal-mining industry. According to ABS Census data, 59% of the combined NSW and QLD coal-mining workforce was over 40 in 2001 (ABS, 2001). This is consistent with worldwide trends of an ageing workforce in industrialised countries, and is also in line with the coal-mining industry in the United States, where the median age of workers was reported as 45.2 years in 2000 (Fotta & Bockosh, 2000).

Figure 2.1 illustrates the age composition of the NSW and QLD coal-mining workforce according to the 2001 ABS Census of Population and Housing, compared with that of the study samples.

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1 According to Coal Services, employment covers all PERSONS working in or about the coal mine or coal preparation plant, in connection with its operation whether employed by the mine operator or by a contractor:

1) including working proprietors;
2) including persons engaged as employees of the operator of the mine, or as employees of a contractor undertaking work relating to coal production, coal preparation or as owner-drivers in the transport of coal from the coal mine to a preparation plant;
3) not including contract employees engaged in civil work;
4) not including workers engaged in the transport of coal from mines and preparation plants to markets.
FIGURE 2.1 Comparison of study group (Surveys 1 and 2) with ABS 2001 Census data on coal-mining employees by age group (NSW and QLD)

As Figure 2.1 illustrates, the proportion of workers across different ages in the study sample is representative of the national coal-mining employee population. Sample 2 also closely represents both the national figures as well as Sample 1 in terms of the age categories. The average age of samples 1 and 2 was 40 (39.9; 40.1). These samples were also very similar in terms of length of time spent working in the coal-mining industry (14.7; 14.8), and the breakdown of miners by mine type (which is discussed further below). A total of 178 mine-workers completed Survey 2.

2.6.2 Response rates

As the survey was administered on-site by the same investigator, the number of respondents was limited only by the availability of workers in relation to work demands rather than individual unwillingness to participate. Consequently, the response rate at each site was high and of those asked to participate in the study, 97.3% agreed to complete, and completed, the survey. By way of comparison, in one German study, public transport drivers in Munich were asked to fill in the WAI questionnaire and another survey instrument at the same time. Even though administered during paid work time, only 63% (122 of 193 participants) completed both questionnaires (Karazman et al., 2000).

In this study, at half the participating sites, 90% of the total workforce was approached to participate. At the remaining sites, 50% or less had this opportunity. The variability in participation rates is largely a function of the logistics of collecting data at distal locations and gaining access to workers with
varying roster patterns and cycles. There was no selection of particular groups of workers, but at many sites the Research Assistant could not visit on days that would allow all shifts and crews to participate. This was essentially a random variable in the sampling process.

The WAI was designed for use in conjunction with occupational health care assessments or for workplace surveys (Tuomi et al., 1994). In other studies utilising the Index, a number of methods have been used to administer the questionnaire, with varying degrees of success. In the largest known administration of the Work Ability Index, a European Commission-sponsored study of nurses’ early exit from the profession (NEXT, 2005), a mass mail-out of 77,681 WAI questionnaires to more than 500 institutions in 10 countries yielded an overall response rate of 51.4% (n = 39,898), ranging from 32.4% in Great Britain to 76.9% in Finland.

A similar return rate (52%) for mailed WAI questionnaires was reported in a study of Dutch construction workers (de Zwart et al., 2002), and also for a mailed questionnaire investigating the incidence of occupational injury among younger and older workers (Pransky et al., 2005b). A slightly lower rate of return (46%) was recorded in a study of Austrian bus drivers (Kloimuller et al., 2000).

Liira et al. (2000), in a study of Finnish construction workers, interviewed 961 respondents in the workplace. Four years later, 736 (77%) of the original sample participated in a follow-up telephone interview. The Danish National Work Environment Cohort Study administered the WAI by telephone interview to more than 5000 employees from all sectors of the workforce, recording an 80% participation rate (Nielsen, 1999).

Not surprisingly, higher response rates can be yielded from ‘captive’ participants. For example, complete or almost complete compliance has been reported when the WAI questionnaire has been administered in conjunction with occupational health examinations (de Zwart et al., 2002), functional fitness testing (Punakallio et al., 2004) or routine medical check-ups (Kiss et al., 2002).

2.6.3 Mine site characteristics

The participating mine workers were employed at 16 mine sites (10 open-cut; 6 underground) of both large (workforce over 500) and small (less than 90) operations in the Bowen Basin, QLD and the Hunter Valley, NSW. The mining operations utilised a variety of mining methods, including longwall and highwall, dragline, shovel and truck. The study sites represented 10% (5/49) of NSW and 25% (11/45) of QLD coal-mining operations.

Figure 2.2 compares the proportion of study participants by type of mining operation with that for the NSW and QLD total industry figures for open-cut and underground operations.
Data sources: Coal Services (2005); NRM (2004).

**FIGURE 2.2 Proportion of coal industry workers in Queensland and New South Wales (total) by mine type (industry and study samples)**

Figure 2.2 shows that samples 1 and 2 closely follow the approximate 65:35 open-cut to underground ratio of the industry population, illustrating that both samples are also representative on this measure.

2.6.4 Workforce demographics

Figure 2.3 shows the proportion of study participants in sample 1 for each occupational category in underground and open-cut mine types.
As this figure illustrates, operators-maintainers/mine workers were the predominant work category at both underground (45%) and open-cut sites (68%). Professional/administration staff account for the smallest proportion (3%) of open-cut employees, while electricians (9%) accounted for the smallest proportion of underground employees in the study sample.

Figure 2.4 represents the average age of study sample 1 by mine type and job category.

**FIGURE 2.3** Study sample 1 by mine type and job category

**FIGURE 2.4** Average age of study sample 1 by mine type and job category
As the figure shows, the deputy categories in both underground and open-cut and professional category in open cut had the highest average age, probably reflecting the seniority that comes with age-associated job experience. Mechanics/fitters are the youngest overall employees in the study sample by job category. The overall mean age across occupation types ranged from 35 to 45 years.

2.6.4.1 Employment status

In terms of employment status, 76% of the sample considered their work status to be permanent, while 24% described themselves as contractor. Direct employees (‘permanents’) were slightly older (mean age 40.4 years) than their contract colleagues (mean age 38).

Figures provided for Queensland (BMP/CFMEU) indicate that as at 30 June 2004, 68% of the state’s coal industry workers were employed directly by mine operators, while 32% were contract employees. Comparable figures were not available for NSW. The actual number of contractors may be understated in the Queensland figures, as some sites operating totally on contract labour list their employees as ‘direct’ employees. The ratio of direct mine employees to contractors is similar across mine types (see Table 2.5).

**TABLE 2.5 Direct (permanent) and contract employees by mine type (Queensland) as at June 2004**

<table>
<thead>
<tr>
<th></th>
<th>Direct employees n (%)</th>
<th>Contract employees n (%)</th>
<th>TOTAL n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open-cut</td>
<td>6665 (67%)</td>
<td>3325 (33%)</td>
<td>9990</td>
</tr>
<tr>
<td>Underground</td>
<td>2277 (71%)</td>
<td>925 (29%)</td>
<td>3202</td>
</tr>
<tr>
<td><strong>TOTAL WORKFORCE</strong></td>
<td><strong>8942 (68%)</strong></td>
<td><strong>4250 (32%)</strong></td>
<td><strong>13192 (100%)</strong></td>
</tr>
</tbody>
</table>

Source: Bureau of Mining and Petroleum/CFMEU

By comparison, in 2003 in the US coal-mining industry, the ratio of permanent mine operator employees to contractors was about 5:1 (NIOSH, 2004a).

2.6.4.2 Length of time in industry

Average length of employment of the participants in the survey was 14.5 years (range <1-51 years), with a relatively even distribution between mine types (14.6 open-cut; 14.3 underground). Direct (permanent) employees had on average about 5 years’ longer mining experience (mean 15.8 years) than contractors (10.5). In terms of job description, deputies/supervisors reported the longest average years of mining experience of all job categories in both mine types (20.7 underground; 18.9 open-cut), followed by open-cut professional/administration staff (17.6). In the rest of the occupational categories (electrician, mechanic or
fitter, operator-maintainer/mine worker) the average years of experience in coal mining was quite similar between open-cut and underground staff, ranging from 12 to 14 years. See Figure 2.5.

![Chart showing years in industry by mine type and job category.](image)

**FIGURE 2.5** Number of years in coal-mining industry by mine type and job category (study sample)

2.7 DATA MANAGEMENT

The completed questionnaires were given a unique identification number and delivered to a data entry organisation after consultation regarding coding of the responses to each question. The surveys remained in a secure location while held with the data entry organisation. The QUT research team received the electronic and coded information in the form of comma-delimited ASCII files. These files were then imported into Microsoft Excel.

Data checks and processes to ensure data integrity took place before any statistical procedures were carried out. Confirmation with the data entry organisation ensured each question was coded correctly and on return of the hard copy surveys to QUT, approximately 10% (of the entire sample of 1624) was matched with the electronic data files. Any minor errors in data entry were identified, logged and corrected prior to analysis.

2.8 STUDY FACTORS, MEASURES AND DATA ANALYSIS

After checking data, removing invalid entries or cases and arranging the data, two levels of analysis were undertaken. The first involved the calculation of descriptive statistics for the main variables. In some instances this required frequency counts, while for interval or ratio data, means and standard deviation
values were obtained. All statistical analyses were undertaken with Microsoft Excel for data editing and data cleaning, while the descriptive statistics and ANOVAs used SPSS (v. 12.0.1) or Statistica (v. 6.1). All tables and figures use weighted means, which take sample size into account. (The weighted mean is equivalent to the sum of the means times the number of observations in each sample divided by the total number of observations in the combined samples) (Osborn, 2000).

The second level of analysis involved the calculation of Analyses of Variance (ANOVAs) for a range of measures. The major design used was a fully-crossed, three-factor, between-subjects ANOVA, in which AGE GROUP (4 levels: 20-29, 30-39, 40-49, 50-59); MINE TYPE (2 levels: open-cut or underground); and JOB (5 levels: Operator-Maintainer/Mine Worker, Electrician, Mechanic/Fitter, Deputy, and Professional/Administration) were the independent variables. This design enabled the statistical significance of each of these three independent variables with respect to each dependent measure, as well as interactions between them to be determined. Interactions were considered to be of particular importance as, for example, the effect of age on a given measure may differ significantly between open-cut and underground workers, or across the major job categories. This was a major factor in choosing ANOVA over regression methods for the second level of analysis. In the case of the analysis of medical conditions, a fourth independent variable (DIAGNOSIS TYPE) with two levels (“own opinion” and “doctor’s diagnosis” was added). In these cases the ANOVA used was a mixed model in which DIAGNOSIS TYPE was a repeated measures factor.

For the purposes of these analyses, some job categories were combined, for example, the relatively small numbers of Coal Preparation Plant workers were classified under the Operator-Maintainer/Mine Worker grouping. This enabled a fully balanced design to be achieved. For the same reason, the very small numbers of employees in their teens or over 60 were excluded from the ANOVAs.

There are two caveats with respect to the ANOVAs. In a number of cases, not all the assumptions of ANOVA were met. This included a number of instances in which the homogeneity of variance assumption was not met, and others where the data departed from a normal distribution. To address the former, Greenhouse-Geisser and Huynh-Feldt corrections were examined to ensure that variables found to be significant without correction were also significant when these corrections were used. With respect to the latter, post-hoc comparisons generally used the Games-Howell procedure, a distribution-free statistic. There were also a number of instances in which the $n$ values in each cell were quite unequal. However, in the large majority of cases the minimum $n$ was sufficiently high to obtain adequate variance estimates. Where small $n$’s had the potential to compromise the outcome, data were pooled over fewer independent variables and higher order interactions were not examined further.

For clarity of presentation relevant $p$ values are stated, but $F$-ratios and degrees of freedom ($df$) in connection with results are not reported. Table 2.6 shows the $df$ associated with each factor.
TABLE 2.6 Degrees of freedom (df) for study factors

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
</tr>
</thead>
<tbody>
<tr>
<td>MINE TYPE (MT)</td>
<td>1</td>
</tr>
<tr>
<td>JOBS (J)</td>
<td>4</td>
</tr>
<tr>
<td>AGE CATEGORY (AC)</td>
<td>3</td>
</tr>
<tr>
<td>MT x J</td>
<td>4</td>
</tr>
<tr>
<td>MT x AC</td>
<td>3</td>
</tr>
<tr>
<td>J x AC</td>
<td>12</td>
</tr>
<tr>
<td>MT x J x AC</td>
<td>12</td>
</tr>
</tbody>
</table>

2.8.1 Categorisation of comments for open-ended question in Survey 1

The final item on the initial survey elicited open-ended responses to the following statement:

*List the three most important things you believe would help older miners continue working safely and productively as long as they wish.*

All comments (n = 3306) were entered into a database, and then categorised at three levels. Each comment was categorised at the first level (major topic), the majority at a second (sub-topic) level, and many at the third (modifier) level.

The procedure for categorisation addressed three questions, in the following order:

1. *Which of the following 10 topics does the comment primarily address?* Most comments could be fairly readily assigned to a category, though in some cases two or more categories overlapped closely (e.g. safety, training, ergonomics). In such cases the coder chose the topic that appeared to be of major concern to the respondent. One word comments (e.g. “training” could generally not be classified beyond the first level. However, in some cases, the single word (e.g. “seats” referred to the second level category but implied a single main topic category - e.g. “ergonomics”).

2. What specific topic within the major category does the comment primarily address? A separate list was devised for each major category.

Categories for the first two levels are summarised in Table 2.7.
### TABLE 2.7  Categorisation of comments for open-ended question in Survey 1

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ERGONOMICS</strong></td>
<td>Comments related to the design, availability and operation of machinery, equipment and vehicles, and the match between equipment, task and the operator</td>
</tr>
</tbody>
</table>
| Sub-topics   | Access  
|              | Crib rooms  
|              | Lighting  
|              | Machinery  
|              | Roads  
|              | Seating  
|              | Work environment |
| **FINANCIAL** | Comments related to pay, tax, superannuation, or other matters concerning remuneration               |
|              | Pay  
|              | Superannuation  
|              | Tax  
|              | Bonuses  
|              | Incentives |
| **HEALTH**   | Comments concerning the health and physical fitness of workers, including specific medical conditions and/or injuries, and physical capacity to undertake work |
|              | Fitness  
|              | Health  
|              | Nutrition and diet  
|              | Sick leave  
|              | Sleep  
|              | Weight control  
|              | Injury Rehabilitation  
|              | Rest  
|              | Stress  
|              | Fatigue |
| **MANAGEMENT** | Comments about management practices or policies other than those directly concerning safety, work organisation or specific work tasks |
|              | Appreciation of staff  
|              | Attitudes towards staff  
|              | Communication  
|              | Job security  
|              | Retirement policies  
|              | Roles and responsibilities  
|              | Skills |
| **SAFETY**   | Comments that relate primarily to safety policies, practices and issues                                 |
|              | Chemicals  
|              | Environment  
|              | Experience  
|              | Risk assessment  
|              | Safety attitudes  
|              | Safety performance  
|              | Safety priorities  
|              | Safety training  
<p>|              | Individual Safety |</p>
<table>
<thead>
<tr>
<th>TASKS</th>
<th>Comments about specific work tasks, their type, amount, intensity and allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Allocation</td>
</tr>
<tr>
<td></td>
<td>Effort</td>
</tr>
<tr>
<td></td>
<td>Favouritism – not used</td>
</tr>
<tr>
<td></td>
<td>Job rotation</td>
</tr>
<tr>
<td></td>
<td>Jobs/duties</td>
</tr>
<tr>
<td></td>
<td>Pacing</td>
</tr>
<tr>
<td></td>
<td>Physical demands</td>
</tr>
<tr>
<td></td>
<td>Training in tasks</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TRAINING</th>
<th>Comments concerning the content, methods, frequency and mode of delivery of training</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Apprenticeships</td>
</tr>
<tr>
<td></td>
<td>Frequency</td>
</tr>
<tr>
<td></td>
<td>Mode of delivery</td>
</tr>
<tr>
<td></td>
<td>New staff</td>
</tr>
<tr>
<td></td>
<td>Topics</td>
</tr>
<tr>
<td></td>
<td>Training on specific machinery</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WORK ORGANISATION</th>
<th>Comments dealing with the structure of rosters, shifts, crew numbers, including length of work, breaks, etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crew levels</td>
</tr>
<tr>
<td></td>
<td>Job sharing</td>
</tr>
<tr>
<td></td>
<td>Leave/holidays</td>
</tr>
<tr>
<td></td>
<td>Rest breaks</td>
</tr>
<tr>
<td></td>
<td>Rosters</td>
</tr>
<tr>
<td></td>
<td>Shifts</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>INDIVIDUAL ISSUES</th>
<th>Comments relating primarily to individual employees’ attitudes, approaches, career or personal priorities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adaptability</td>
</tr>
<tr>
<td></td>
<td>Attitude</td>
</tr>
<tr>
<td></td>
<td>Awareness</td>
</tr>
<tr>
<td></td>
<td>Care</td>
</tr>
<tr>
<td></td>
<td>Knowledge</td>
</tr>
<tr>
<td></td>
<td>Limitations</td>
</tr>
<tr>
<td></td>
<td>Motivation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SOCIAL RELATIONSHIPS</th>
<th>Comments concerning relationships at work, whether in crews or other groups, including positive and negative aspects of interpersonal relationships at work</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Attitudes</td>
</tr>
<tr>
<td></td>
<td>Appreciation</td>
</tr>
<tr>
<td></td>
<td>Friendship</td>
</tr>
<tr>
<td></td>
<td>Work culture</td>
</tr>
<tr>
<td></td>
<td>Enjoyment</td>
</tr>
</tbody>
</table>

3. What type of change, if any, is the respondent advocating? These varied with the main category and sub-category, but many comments could be allocated a ‘modifier’; for example, *decrease, increase, match better, modernise, provide support for, screen for*.

A small number of comments on issues unrelated to the survey were not coded or analysed.
2.9 STRENGTHS AND LIMITATIONS OF THE STUDY

2.9.1 Strengths

This study attracted a high participation rate among a large and representative sample of the Australian coal-mining workforce and is the first to apply the WAI to the coal-mining industry. The cross-sectional design used in the study allowed the collection of useful data relatively economically and quickly and was most practical in the mining setting.

The design also provides a useful snapshot of factors of interest to the industry at an important stage in its development and more detailed information than studies using administrative data only, for example injury surveillance or workers’ compensation data. Injury surveillance data in the Australian coal-mining industry has been shown to be unsuitable for interstate comparisons (Driscoll, 2004).

The inclusion of supplementary questions allowed for industry-specific analyses which enhance knowledge of the influence of work conditions, work environment and individual factors on the WAI scores.

Importantly, the results of this study will allow the identification of areas for potential intervention and a source of information for future research.

2.9.2 Limitations

The current study has certain limitations that should be considered when interpreting the results. Descriptive study designs, such as the cross-sectional survey method used in this study, have inherent weaknesses. The results are descriptive only and although suggestive of risk factors, no temporal or causal relationships can be unambiguously inferred.

In terms of injuries and diseases, the results of this study provide prevalence rates only and do not describe incidence.

Self-report data is also prone to recall bias among participants. For example, the method of administration of the survey (self-report) suggests that the results are likely to underestimate the actual number of medically diagnosed conditions, therefore possibly inflating the WAI scores.

Responses elicited in workplace surveys can also be influenced by issues such as job security. A recent study in the US mining industry found that several factors, including a worker’s fear of losing his/her job and health insurance status, contributed to under-reporting of disease and illness information (Scott et al., 2004). The clear confidentiality and anonymity procedures should have alleviated most such concerns, but they cannot be altogether excluded.
In addition, some of the definitions of illnesses which formed part of the standard WAI may have been confusing to some respondents. However, the presence of a researcher to answer questions during the completion of the questionnaire should have reduced any effect of this problem.

It is also recognised that measures of exposure (e.g. to environmental factors, physical loading etc.) could not be verified independently. Imperfect or biased recall has the potential to distort such ratings, especially since respondents were sometimes asked to rate such exposure over their career in the industry. In consequence, data using these exposure ratings should be regarded as indicative rather than definitive.

Limitations in the statistical analysis included uneven numbers in various cross-tabulations, and the fact that some job types have relatively high variances due to the range of actual tasks and duties they entail.
SECTION 3    RESULTS

- Age-related changes in work ability
- Work ability, work demands and injury in older workers
- Individual health factors and work ability
3.1 AGE-RELATED CHANGES IN WORK ABILITY

As detailed in the Methods section, the Work Ability Index (WAI) score is determined from the answers to a series of questions regarding the worker’s personal capacity to meet the physical and mental demands of their job, as well as the worker’s health status. The questions are included in seven ‘items’:

1. Current work ability compared to lifetime best.
2. Current work ability in relation both to the physical and mental demands of work.
3. Number of diagnosed diseases.
4. Estimation of work impairment due to disease.
5. Sickness absence during the past year.
6. Own prognosis of work ability after two years.
7. Mental resources.

There are two ways in which the WAI has been presented in previous studies: either through analysis of the obtained WAI score as a continuous variable (presented with standard descriptive statistics) or by presenting the frequencies for WAI data in each of four categories designated “excellent”, “good”, “fair”, and “poor”. This second method was derived using specific breakpoints in the distribution of WAI from the original longitudinal studies of Ilmarinen et al. (1997).

We first present the overall WAI results by means of this categorisation. Thereafter we use the WAI as a continuous variable, since the actual scores permit finer resolution and more detailed comparisons; principally by analysing scores by variables such as age group, mine type and job category.

The reader should note at the outset that a literal interpretation of the category designations (excellent to poor) should be avoided, because methodological differences between our study and those from which these break-points were determined tend to make the unqualified use of these descriptors, or direct comparison of values with other data-sets, misleading.

These methodological factors are twofold. First, our study used a self-report, survey method rather than individual consultations by an occupational physician. Respondents are less likely to report as many medical conditions when completing a questionnaire as they would when questioned by a physician in an individual consultation. The number of medical conditions is one component of the WAI, so any underestimate would inflate the WAI.

Secondly, work ability may be inflated as a result of the ‘healthy worker’ effect. Any miners not at work at the time of the survey for reasons of poor health or injury could be expected to have poorer than average work ability scores, but would not be counted in the survey. The extent of any such effect is unknown but likely to be small. In any event, while direct comparisons with the absolute
values for other populations should be interpreted with caution, trends with age and other within-group comparisons are more robust and informative.

In addition, readers should bear in mind that these category designations were based on data restricted to those over 45 years of age. When applied to all workers, they inflate the numbers in the better categories.

These caveats notwithstanding, it is useful as a starting point to appreciate the category breakdown at the whole workforce level.

### 3.1.1 Overall WAI scores — categorical analysis

WAI data for the whole sample is presented in Figure 3.1. The skew towards high WAI values is clearly evident, with over three-quarters of the sample being classified in the excellent and good categories. This presentation includes both of the types of overestimate described above (methodological differences and use of categories derived from a population older than the sample). To illustrate the effect of the second factor, we present in Figure 3.2 the same data using categories whose breakpoints have been increased by 2 points. This is a very conservative adjustment, since Geissler et al. (2005) have shown that the WAI returns values more than 2 points higher when a psychologist rather than a physician obtains data individually from participants. This small adjustment immediately decreases the number of miners in the excellent category to 60% of its unadjusted level.

![Figure 3.1](image-url)  
**FIGURE 3.1**  Proportion of Sample 1 by WAI category
**FIGURE 3.2 Proportion of Sample 1 by adjusted WAI category**

In the second pair of Figures (3.3 and 3.4), we show results only for miners of 45 years and above. This corresponds appropriately to the data on which the categories were originally based. As before, Figure 3.3 used unadjusted scores, while Figure 3.4 uses a conservative 2-point adjustment to allow for the use of a self-report method. While in both instances there remains a skew towards the better WAI categories, this is markedly reduced in the adjusted figures.

**FIGURE 3.3 Proportion of Sample 1 by WAI category (respondents aged 45+ only)**
In summary, this categorical presentation of the data shows a spread of WAI scores in this sample of the Australian coal-mining workforce across all four categories of work ability, with a preponderance of scores in the higher categories. Only a small percentage of miners - independent of any adjustments to the data and whether or not comparisons are made with age range controlled - lie in the ‘poor’ category.

3.1.2 Overall WAI scores – continuous variable analysis

The overall mean WAI of the survey respondents in this study was 42.3 (mean age 39.9). For comparison, the mean WAI of municipal workers with a mean age of 46.9 in the Finnish longitudinal study was 40 (Tuomi et al., 1997). This group included employees with a wide range of job types. Studies of other populations have also found lower WAI values than our coal-mining sample. For example, German metropolitan transport authority drivers (bus, tram, subway) with a mean age of 50 had an average WAI score of 37 (Karazman et al., 1999), and Austrian bus drivers with a mean age of 43.7 had an average WAI of 36.8 (Kloimuller et al., 2000). Details of these and other studies are shown in Table 3.1. Some groups have been shown to have WAI scores similar to the current coal-mining sample despite being, on average, more than 10 years older (Dutch construction workers: 40.5, Belgian fire-fighters: 40.6, see Table 3.1). The WAI of the current sample is thus quite similar to these two overseas workforces, both of which involve a roughly comparable range of physical work, driving and equipment use.
TABLE 3.1 Work Ability Index scores by occupation and setting from comparable studies

<table>
<thead>
<tr>
<th>OCCUPATION</th>
<th>SETTING</th>
<th>AGE</th>
<th>WAI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal-mining workforce (n = 1624)</td>
<td>Australia</td>
<td>39.9</td>
<td>42.3</td>
</tr>
<tr>
<td>Emergency nurses (n = 54)</td>
<td>Brazil</td>
<td>37</td>
<td>42</td>
</tr>
<tr>
<td>Municipal fire fighters (n = 236)</td>
<td>Belgium</td>
<td>51.5</td>
<td>40.6</td>
</tr>
<tr>
<td>Construction workers (n = 859)</td>
<td>Netherlands</td>
<td>51</td>
<td>40.5</td>
</tr>
<tr>
<td>Food industry (n = 126)</td>
<td>Finland</td>
<td>62</td>
<td>37.3</td>
</tr>
<tr>
<td>Transport workers (n = 122)</td>
<td>Germany</td>
<td>50</td>
<td>37</td>
</tr>
<tr>
<td>Bus drivers (n = 369)</td>
<td>Austria</td>
<td>44</td>
<td>36.8</td>
</tr>
<tr>
<td>Industrial workers (n = 277)</td>
<td>Estonia</td>
<td>37</td>
<td>32.5</td>
</tr>
</tbody>
</table>

*Sources*: Parker et al (current study); Duran & Cocco, 2004; Kiss et al, 2002; De Zwart et al., 2002; Karazman et al., 1999; Salonen et al., 2003; Kloimuller et al., 2000.

3.1.3 Contribution of component items to WAI score

In the current study, each component of the WAI was significantly and positively correlated with the overall WAI score. The Pearson Product Moment correlation coefficients were, in descending order:

- Number of diagnosed diseases       \( r = 0.68 \)
- Current work ability compared to lifetime best \( r = 0.66 \)
- Current work ability relative to the physical and mental demands of work \( r = 0.64 \)
- Estimation of work impairment due to disease \( r = 0.63 \)
- Mental resources \( r = 0.48 \)
- Own prognosis of work ability after two years \( r = 0.47 \)
- Sickness absence during the past year \( r = 0.38 \)

The number of diagnosed diseases proved to be the best single predictor of overall WAI scores in this study. This item has been a good predictor of overall scores in other studies as well, although the originators of the Index have found the rating of work ability relative to lifetime best to be the best single predictor of the overall WAI score (Tuomi et al., 2001). This item was the second most highly correlated in this study. Subsequent research has confirmed a high correlation between subjective estimates of current work ability and the overall WAI score (Makowiec-Dabrowska et al., 2000). In turn, poor scores for this item have been reported elsewhere as predictive of premature departure from working life (Salonen et al., 2003). A recent study of railway tunnel construction workers also showed work ability relative to lifetime best to be one of the most
important factors explaining the total WA I score (Capanni et al., 2005). On the other hand, as in the current study, sick leave in the previous year has proven to be the item least well correlated with the overall score.

### 3.1.4 WAI score by age group and mine type

To analyse the WAI and other variables with respect to age, the latter was converted from a continuous to a categorical variable by the division of respondents into six age groups: <20, 20-29, 30-39, 40-49, 50-59 and ≥60. Final analysis excluded workers in their 60s and those less than 20, since there were very small numbers in some combinations of mine type and job category, which would have rendered comparisons invalid. Fifteen employees in their teens, 23 in their 60s and one employee over 70 were excluded. This represents 2.4% of the overall sample. Figure 3.5 shows the WAI scores for the four age groups, with open-cut and underground values presented separately.

**FIGURE 3.5 WAI score by age group and mine type (mean ± 95% CI)**

WAI scores were significantly lower in underground than open-cut miners overall (p < 0.05), although the average difference was less than one point. The WAI scores also decreased in each successive age group in the current sample. Post-hoc comparisons showed that workers in the 40-49 and 50-59 categories had a significantly lower WAI than those in the 20-29 age category. This finding is consistent with studies of other industries, which have shown the WAI to decline with age, especially among workers in physically demanding occupations (Tuomi et al, 1991; Ilmarinen et al, 1997; Louhevarra et al, 1999; Ilmarinen & Rantinen,
The overall difference of about 3.5 points from the 20-29 to the 50-59 age groups is substantially less than the decline of approximately 0.6 points per year found in the municipal employee study of Ilmarinen et al. (1997), which would be equivalent to a drop of 18 points if translated directly to our population. However, the current study uses cross-sectional data while the Finnish study was longitudinal. Cross-sectional studies tend to underestimate age changes because those in the older age groups whose work ability has declined the most will tend to retire early or move to other employment. They would therefore be under-represented in the older age-groups. In other words, older miners may represent a population of ‘survivors’ who are healthier than the cohort who joined the industry at the same time as they did, but subsequently left. Actual effects of ageing on individuals are better gauged through the use of longitudinal methods, but these are prohibitive in terms of cost and impractical for other than relatively short periods of time unless collected routinely.

Results from other cross-sectional studies of work ability in physically demanding occupations can be informative if not directly comparable. For example, a study of 1485 Polish workers from various occupational groups found that WAI scores were statistically significantly lower for those working in painful or tiring positions, and carrying or moving heavy loads (Bugajska & Lastowiecka, 2005). A recent study of railway tunnel construction workers in Italy showed that age, the physical demands of work, and shiftwork accounted for most of the variation in WAI scores in that workforce (Capanni et al., 2005).

### 3.1.5 Differential effects of age group on WAI for underground and open-cut mining

Although there was no statistically significant interaction between age category and mine type, underground miner WAI values decreased with age at about three times the rate of those for open-cut miners across the four age groups. Planned comparisons showed that while there were no significant differences between underground and open-cut miners in the two younger age groups, underground workers showed a significantly lower WAI than their open-cut counterparts in the 40-49 year-old and 50-59 year-old age categories (p < 0.01 and p < 0.05 respectively). These differences are depicted in Figure 3.5.

There are three potential reasons for this more pronounced drop in WAI among underground miners, the first of which may be excluded:

1. If miners in the underground sector stay in the industry for significantly longer than open-cut employees, this would have the effect of selectively underestimating real age-related declines in the open-cut relative to the underground group, as the older open-cut age-groups would have fewer long-serving miners. The evidence does not support this: Table 3.2 shows that the number of years in the industry is almost identical (and not significantly different) for the two groups, and that underground miners
have on average spent approximately 18 months less in their current job than for open-cut employees).

**TABLE 3.2  Experience in industry and current job by mine type**

<table>
<thead>
<tr>
<th>Mine Type</th>
<th>Years in Industry (mean ± SD)</th>
<th>Years in current job (mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open-cut</td>
<td>14.6 ± 9.8</td>
<td>7.2 ± 7.6</td>
</tr>
<tr>
<td>Underground</td>
<td>14.4 ± 9.1</td>
<td>5.7 ± 5.5</td>
</tr>
<tr>
<td>T-test</td>
<td>n.s. (p &gt; 0.5)</td>
<td>p &lt; 0.0005</td>
</tr>
</tbody>
</table>

2. The difference may reflect real differences in the nature of the two types of mining, such that older underground miners are working closer to their maximum capacity. Underground mining involves workers in more physically demanding jobs, often carried out in challenging environmental conditions. Thus, even with equally good health, older underground miners may have a poorer WAI because they rate their work ability lower relative to lifetime best or to the demands of work.

3. *Underground work may result in a greater actual degradation of health and functional capacity* than for equivalent jobs in open-cut, even though they rate their work ability no differently from open-cut miners.

Unlike the age-group effect, the greater decrease in underground than open-cut miners cannot be explained by the cross-sectional design of this study and is very likely to reflect genuine differences in the effects of underground and open-cut work.

Examination of the components of the WAI suggest that the second explanation is predominant, that is, the older underground miners show a greater decrease in their rating of work ability both relative to lifetime best and with respect to physical (but not mental) demands of the job, compared to open-cut miners. While there was no contribution to this effect from the total number of medical conditions, a small part of the difference — at least in the two middle decades — was seen in the self-rated effects of any medical conditions. These comparisons are shown in Table 3.3.

In Australia, underground mining attracts a higher risk of injury than above-ground mining operations, as illustrated in Table 3.4, which shows the frequency and incidence rates for lost-time injuries to be two to three times higher in underground mines compared to open-cut operations. The steeper decline in WAI scores with age for underground miners in the current study may be one reflection of this difference in the hazards of each sector. Such patterns are evident in other populations. Kiss et al. (2002) for example, in a study of firefighters, found the presence of musculoskeletal disorders (OR 7.7) or cardiovascular conditions (OR 3.8) to be more strongly correlated with poor WAI scores than age (OR 1.3).
TABLE 3.3  Contribution of WAI components to differences between open-cut and underground WAI scores, by age group

<table>
<thead>
<tr>
<th>Component of WAI</th>
<th>20-29</th>
<th>30-39</th>
<th>40-49</th>
<th>50-59</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work ability vs. lifetime best</td>
<td>ns</td>
<td>ns</td>
<td>OC &gt; UG, p &lt; 0.05</td>
<td>OC &gt; UG, p &lt; 0.05</td>
</tr>
<tr>
<td>Work ability relative to physical demands</td>
<td>ns</td>
<td>ns</td>
<td>OC &gt; UG, p &lt; 0.001</td>
<td>OC &gt; UG, p &lt; 0.05</td>
</tr>
<tr>
<td>Work ability relative to mental demands</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Number of medical conditions</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Effects of medical conditions</td>
<td>ns</td>
<td>OC &gt; UG, p &lt; 0.05</td>
<td>OC &gt; UG, p &lt; 0.05</td>
<td>ns</td>
</tr>
<tr>
<td>Sick leave in last year</td>
<td>ns</td>
<td>ns</td>
<td>OC &gt; UG, p &lt; 0.05</td>
<td>ns</td>
</tr>
<tr>
<td>Own forecast of WA in 2 years</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Mental resources</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

(ns: non-significant difference (p >0.05) between open-cut and underground workers; OC > UG: higher WAI component in open-cut workers)

TABLE 3.4  Lost-time injuries in NSW coal mines 2001 - 2003

<table>
<thead>
<tr>
<th>Lost-time injury frequency rate*</th>
<th>2001-02</th>
<th>2002-03</th>
<th>2001</th>
<th>2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>underground</td>
<td>27</td>
<td>23</td>
<td>33</td>
<td>24</td>
</tr>
<tr>
<td>open-cut</td>
<td>38</td>
<td>36</td>
<td>43</td>
<td>35</td>
</tr>
<tr>
<td>Lost-time injury incidence rate#</td>
<td>5</td>
<td>4</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>underground</td>
<td>7</td>
<td>6</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>open-cut</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

Source: Coal Services (2004). * Summary of New South Wales Black Coal Statistics. * per million hours worked    # per 100 employees

3.1.6  WAI score by mine type and job category

There was a statistically significant difference in the WAI scores between the job categories used in this analysis (p < 0.05). Post-hoc tests (Games-Howell) confirmed that deputies, trades-people and mine-workers had significantly lower WAI scores than professional/administration staff in the open-cut sector, but this was not true in the underground miners. Open-cut employees had a higher overall WAI than underground miners in each job category, except electricians. It is unclear why electricians in the open-cut sector had higher work ability scores than those who work in the underground sector. No other comparisons were statistically significant. The relative lack of sensitivity to the occupational groupings used here is likely to result from the high variability of task and environment within these groupings. The operators-maintainers/mine workers category is both the largest numerically and also the most diverse with respect to tasks. The comparison of workers in the various groups with respect to tasks is presented in Section 3.3.
3.1.7 WAI score by employment status

Contract and permanent workers had very similar WAI scores overall, with a mean of 43.1 and 42 respectively, but the approximately one-point advantage for contract workers was statistically significant (p < 0.05).

This group difference is shown in Figure 3.7 and was evident in the three older age groups but not for those in the 20-29 category, and the interaction between age group and contractor/permanent status was statistically significant (p < 0.05). The difference between the two was smaller for the 50-59 year-olds than for the middle two age groups. Among the different work categories, electricians in the contractor group had the highest WAI, in contrast to the same work category in permanent workers, who recorded the lowest work ability score.

*FIGURE 3.6 Work Ability Index score by job category and mine type (mean ± 95% CI)*
A recent US study of high-risk industries and occupations revealed that in 2002, the proportion of injured workers over the age of 44 was higher among directly employed coal industry workers than independent contractors (NIOSH, 2004a). In the period 1993-2002, the rate of lost-time injuries was consistently lower overall for independent contractors compared to those directly employed by coal mine operators in the underground setting. The reverse was true for surface operations, for which coal contractors had a higher rate than all other surface mine workers.

Evidence from the US mining industry for 1988-1997 shows that directly employed coal workers had the highest rate of lost-time injuries in the total mining workforce; at almost twice the rate of contract coal workers (NIOSH, 2002). The rates for underground coal miners were similar, however, suggesting that the discrepancy is concentrated in open-cut operations. More recent data for 2003 confirms a similar injury incidence rate among underground coal workers for directly employed and contract workers (NIOSH, 2005).

Our survey found a somewhat higher overall WAI score in contractors than in direct/permanent employees. This finding should be treated with caution, however, as many factors vary in conjunction with permanent/contractor status, including the work environment and type of work, as well as demographic factors. In this study, which was not designed to focus on this question, such potential confounds could not be ruled out. Specifically, it was not possible to include employment status with mine type, age group and job in a complete analysis, as the numbers in some cells would be inadequate. A study focussed
specifically on permanent/contractor status would be required, as this could control for type of work and other relevant variables.

3.1.8 Self-rated work ability

Respondents were asked to estimate their current work ability (how well they are able to carry out their job safely and effectively) compared to their lifetime best on a scale of 0 (totally unable to work) to 10 (work ability at its best).

The mean score on this variable for Sample 1 was 8.4. Results from other studies have yielded scores ranging from a high of 9.4 among Mississippi university employees (Williams & Crumpton, 1997) and Finnish home care workers at 8.2 (Pohjonen & Ranta, 2001) to 7.2 among Munich public transport workers (Karazman et al., 2000) and 6.9 for Austrian bus drivers (Kloimuller et al., 2000).

In the current study a significant difference between job categories was apparent. Operators-maintainers/mine workers estimated current work ability more highly than any other job category (see Figure 3.8). Open-cut electricians reported the lowest current work ability. Post-hoc comparisons (Games-Howell) indicated a significant difference between these two categories (p < 0.05) but not between any others. This single variable differs somewhat from the more comprehensive rating provided by the total WAI score, for example, it does not reveal the overall sector difference nearly as strongly as the overall WAI index.

![Current self-estimate of work ability compared to lifetime best by mine type and job category (mean ± 95% CI)](image-url)
3.1.9 Summary

The Australian coal-mining workforce has an overall WAI that is comparable to two other industries involving physical tasks, driving and equipment use (firefighting and construction). Direct comparisons should be treated cautiously, however, because of demographic and methodological differences.

Consistent with the findings from other industries, the results confirm that mine workers in the older age categories, i.e. over 40 years, have significantly reduced work ability compared to their younger counterparts. This is evident despite the fact that a cross-sectional design minimises real changes with age in a particular cohort.

Although the overall decrease in the older age groups was not large, it was approximately three times greater in the underground than the open-cut population. In particular, older underground miners rated their work ability lower than did their open-cut counterparts relative both to lifetime best and to the physical demands of the job.

The reason for this difference is not completely clear and there are several possible explanations, but initial cohort differences appear unlikely and differential attrition between the sectors can be ruled out. A common reason for early departure from the workforce, as well as a relatively lower WAI, relates to the older worker’s relative inability to cope with physically demanding work. While both open-cut and underground mining involve such work, differences in the nature of the work, particularly the underground work environment, may place differential loads on workers in the two operations. Differences in the organisation of work might also occur.
3.2 WORK ABILITY, WORK DEMANDS AND INJURY IN OLDER WORKERS

This section explores two related issues. First, results from those questions in the Work Ability Index which specifically rate the degree of match between an individual’s capacity and the demands imposed by work tasks are outlined. Thus characterisation of work ability and work demands makes use of the WAI but also questions about major duties and work tasks. Second, the differential experience of older injury-free and older injured miners with respect to work ability and work demands is presented. The latter comparisons used a wide range of measures that were included in the survey of the follow-up sample, which are supplemented by findings from the main sample.

These twin issues are significant because work ability and work demands have proven to be related, and because age increases the probability that work demands will exceed work ability for some individuals, or for all or most individuals for some tasks. It is important not only to have a general assessment of how the mining workforce rates the relationship between their capacities and the requirements of the job, but also to learn what differentiates the experience of those older and experienced miners who do or do not report having been injured.

The influence of physical work, in particular, has been highlighted in studies using the WAI showing that by the age of 58, men in physically demanding jobs are twice as likely to fall within the poor work ability category as those performing non-physical labour (Ilmarinen et al., 1997). A particular instance of this difference is reflected in teachers, who, at the age of 50, averaged 10 points more on the WAI than their counterparts in physically demanding jobs (Ilmarinen, 1999). Although the focus of this study is on injury, the WAI also offered some opportunity to explore work ability in relation to mental demands, and for this reason limited data on this relationship has also been included.

A mismatch between the physical requirements of a job and worker capacity has been shown to be associated with work disability and early departure from the workforce (Pransky et al., 2005a). At the population level, physical capacities peak in early adulthood and decline thereafter (Spirduso, 1995) reducing, on average, the “safety margin” between a worker’s capacities and the demands of his or her work. These mismatches have been associated with increased rates of various occupational conditions, such as back pain, a phenomenon that is particularly important for older workers (Zwerling et al., 1996). Thus the general problem of an imbalance of functional capacities and work demands is of special concern in the older segment of the workforce (Bugarska & Lastowiecka, 2005).
3.2.1 Work ability in relation to the physical and mental demands of work

Participants were asked in part of the WAI to rate their current work ability, in terms of both the physical and mental demands of their work, on a scale of very good (5 points) to very poor (1 point). Overall, respondents rated their current work ability quite highly in relation to both the physical and mental demands of the job, with modal responses corresponding to good (4) or very good (5). This is shown in Figures 3.9 and 3.10.

With respect to the physical demands of work, this rating decreased significantly across age groups (p < 0.001), as is apparent in Figure 3.9, which shows these values for miners in both open-cut and underground sectors. There was no significant difference between underground and open-cut workers in this rating, however, despite a tendency, just outside statistical significance levels (p > 0.05), for older underground miners to report lower ratings than the open-cut sample.

![Figure 3.9](image_url)

**FIGURE 3.9** Self-rated work ability in relation to the physical demands of work by age group and mine type (mean ± 95% CI)

There were, however, small but significant differences in these ratings between job categories. Electricians (p < 0.05) and mechanics/fitters (p < 0.05) had significantly lower mean work ability with respect to physical demands of work than those in the operator-maintainer/mineworker category. The latter includes a broad range of duties from highly physical to largely sedentary, so this should not be taken to indicate that all...
operators/maintainers provided higher ratings than those in the trades. Not surprisingly, professional/administrative staff rated their work ability in relation to physical demands at a higher level than all the other groups. In comparison to the trades (electricians and mechanics/fitters), and deputies (p < 0.05), their scores were significantly higher. These data are shown in Figure 3.10.

![Figure 3.10](image)

**FIGURE 3.10**  Self-rated work ability in relation to the physical demands of work by job category and mine type (mean ± 95% CI)

Underground deputies, electricians and mechanics/fitters had significantly lower mean work ability scores than those in the operator-maintainer/mine worker and professional/administrative categories, whether in relation to physical or to mental demands of their work. Electricians, whose ratings were lower than mechanics/fitters on average, showed high within-group variance and thus their ratings did not differ significantly.

While the reasons for these differences cannot be confirmed by the present study, it is possible that the types of field maintenance work required of mechanics/fitters and electricians expose them more frequently to work in awkward or unusual postures, work requiring the exertion of high forces, and generally in less predictable and controlled work environments than most mine workers.

The clear decline across age categories seen for ratings with respect to physical demands was not true for the comparable ratings with respect to mental demands (Figure 3.11), although there was a small drop-off in the oldest age-group. There was no overall difference between how underground and open-cut miners rated their work ability with respect to
the mental demands of their work. Underground deputies, however, gave significantly lower ratings than did underground operator/maintainer mine

![Figure 3.11: Self-rated work ability in relation to the mental demands of work by age group and mine type (mean ± 95% CI)](image)

**FIGURE 3.11** Self-rated work ability in relation to the mental demands of work by age group and mine type (mean ± 95% CI)

![Figure 3.12: Self-rated work ability in relation to the mental demands of work by job category and mine type (mean ± 95% CI)](image)

**FIGURE 3.12** Self-rated work ability in relation to the mental demands of work by job category and mine type (mean ± 95% CI)
workers (p < 0.001) (see Figure 3.12). Open-cut deputies and open-cut electricians (as with several other measures), provided lower ratings than operators-maintainers/mine workers. Because this study did not focus on the mental aspects of work, there was less capacity to probe these results by reference to information from other parts of the survey. In a later section, though, it will be shown that deputies’ self-estimates of office work were surprisingly high, and individual comments support the possibility that they experience high levels of stress from the combination of different duties and demands.

In summary, miners generally rated their work ability as “good” or “very good” with respect to the physical and mental demands of work. These ratings clearly dropped in the older age groups for physical, but only slightly for mental demands, with this age effect apparent primarily in the underground sector. There was no overall difference between open-cut and underground sectors however. Lower ratings for physical demands were provided by mechanics/fitters and underground deputies, and with respect to mental demands, by open-cut electricians.

3.2.2 Major duties

Miners were asked to indicate which of a series of activities they undertook as their major duties. These duties were chosen to represent different functions of the mining workplace, such as drilling, driving vehicles, operating specific equipment (e.g. long-wall shearer). More specialised duties, such as those in the Coal Preparation and Wash Plant, or surveying, were also included. In total, 17 open-cut and 16 underground duties were listed as options.

3.2.2.1 General patterns of major duties

Older workers in the open-cut operator-maintainer/mine worker category were more likely to report specialised functions such as dragline operator, presumably reflecting the increased skill and experience that comes with age. The average age of open-cut operator-maintainer/mine-workers who reported dragline operation as a major duty was 46.1 yrs. vs. 40.4 for those who did not (p < 0.05). Not surprisingly, underground operator-maintainers/mine workers performed more repetitive physical tasks than any other job type. Open-cut mechanics/fitters are often involved in repetitive physical work, regardless of age. There was little change in the frequency of repetitive tasks across age for underground operator-maintainers/mine workers or for open-cut mechanics/fitters.

Some physically demanding tasks showed different patterns in the open-cut and underground sectors. For example, open-cut operator-maintainer/mine-workers reported handling cables, pipes etc. as a “major duty” relatively infrequently compared to their colleagues in the underground sector. In addition to this overall effect, this type of manual handling was more common amongst older workers in open-cut, and less
common amongst older workers in underground. For the 20-29, 30-39, 40-49 and 50-59 age groups the rates were, respectively, 3.9%, 10.1%, 17.6% and 14.7% (open-cut); and 80.6%, 66.7%, 60.0%, and 47.1%, (underground). For most tasks, however, age was not a significant factor in the reporting of major duties.

Deputies reported undertaking supervisory duties at a greater rate than any other job category. Deputies in both mine types also reported the second highest levels of office work/paperwork/computer work behind professional/administrative staff.

### 3.2.2.2 WAI scores and major duties

The WAI scores of those who undertake each listed duty and those who do not were compared. This analysis was conducted separately for the underground and open-cut groups, and examined only those who classified themselves in the “operator-maintainer/mine worker” category, as the most common duties were very seldom undertaken by those in some of the other categories.

**Underground**

There were no statistically significant differences in the WAI between those who reported any of the 15 listed duties and those who did not (p > 0.05 in all cases).

**Open-cut**

Three of the 17 listed duties showed a difference between those who reported undertaking that duty and those who did not.

Specifically, the WAI was significantly lower (p < 0.05, independent groups t-test) for those who reported:

- o driving grader/scraper than those who did not (41.9 vs. 43.1);
- o driving service truck/water cart/other vehicles than those who did not (41.6 vs. 43.1); and
- o handling cables, pipes etc. than those who did not (40.6 vs. 43.0).

Care is needed in interpreting either the presence of a difference or the absence of one. For example, those who undertook these three duties in open-cut mining were also significantly older (p < 0.05) than those who did not. This difference was relatively small in the case of the two driving duties (42.7 vs. 39.2 years; 42.1 vs. 39.7 years, respectively), but was larger for those who reported handling cables, pipes etc. than those who did not (45.3 vs. 39.6). As the WAI showed a clear decrease with age, it is unclear whether the effects result from the duties or from greater age, or from some related factor.
Similarly, the absence of a difference in WAI for many duties (including all those in the underground sector) does not necessarily mean that some duties are not associated with a better or poorer WAI score. For example, underground workers who handled cables, belt structures, ventilation tubes etc. did not score a significantly different WAI, but, in contrast to the open-cut sector, were significantly (p < 0.05) younger: 36.0 vs. 39.7 years. Therefore age or other differences could mask the actual effects of specific duties.

In addition, most miners (other than specialists) undertake multiple duties and do so in many different combinations. This would also make the specific effects of particular duties harder to discern in the current data set. A more detailed analysis of specific duties would require a study specifically designed for this purpose.

### 3.2.2.3 Work tasks

While “major duties” denote categories of mining work, specific activities and actions can occur across a wide range of duties. For this reason, miners were asked to rate how often their work required them to carry out 12 major work tasks or activities: sitting; standing; walking; lifting, carrying or lowering; pushing, pulling or dragging; bending, stooping or twisting; shovelling; repetitive physical work; using tools; operating machinery; supervision of others; and office work.

Of these, three contrasting tasks which represent a spectrum of activities are shown in Figure 3.13 (sitting, repetitive physical work, and office work), broken down by mine sector and job category. Several features will be noted. For “sitting”, the modal response of professional and administrative staff in both sectors was, predictably, “very often”. This was also true, however, for open-cut operator-maintainer/mine-workers, as many of these individuals undertake driving as a major duty. By contrast, their underground counterparts’ modal response for sitting was “seldom” or “sometimes”, as most work activities underground are performed standing, unless driving shuttle cars, other vehicles, etc., a task which would seldom be done for an entire shift.

The modal response for operator-maintainer/mine-workers in both sectors for office work was, as expected, “seldom” or “never”, unlike that for professional/administrative staff, thus showing that the reasons for sitting in the different categories was not the same.

A clear contrast between the operator-maintainer/mine-workers in underground and open-cut operations is seen in the responses for repetitive physical work, with the former’s modal responses corresponding to “seldom” or “sometimes” and the latter’s to “often” or “very often”. Comparable differences were seen in the five other tasks of lifting, lowering or carrying; pushing, pulling or dragging; bending, stooping or twisting, and shovelling (not shown in Figure 3.13). The high levels of repetitive physical
work for mechanics/fitters was also evident, for both sectors, with modal responses at “often” compared, to, for example, open-cut operator-maintainer/mine-workers’ rating of “seldom” or “sometimes”. These sector and job differences in physical and sedentary work will be reflected in different ways in the patterns of injury and disease presented in Section 3.3.
FIGURE 3.13  Self-rated frequency of sitting (top), repetitive physical work (middle), and office work (bottom) by job category and mine type (mean ± 95% CI). (0: ‘never’, 1: ‘seldom’, 3: ‘sometimes’, 4: ‘often’, 5: ‘very often’)
3.2.3 Characteristics of injured and non-injured miners (45 years and over)

One of the major goals of the study was to determine what differences, if any, might exist between those older miners who had remained injury-free and had retained high work ability, and those who had not. This information may provide insights into the characteristics of work tasks, duties, and the work environment, or personal characteristics, behaviours and attitudes which are associated with injury in older miners.

The second survey, while having a much smaller sample, focussed explicitly on these characteristics and is the main source of data used to address this question. Also presented, however, are selected findings from the main sample where these can be compared to the second survey’s results. Unless indicated otherwise, results in this section are from the follow-up sample.

The criteria used to distinguish the two groups were identical for the main sample and the follow-up sample: “injury-free” miners were classified as those reporting no current injuries diagnosed by a doctor, while “injured” miners as those who reported that a doctor had diagnosed one or more current injuries. This distinction is based purely on the self-report data, and does not indicate any objective assessment of the presence or severity of injury. In the main sample, 69 miners in the appropriate age range were thus classified as “injured”, and 258 as injury-free, while in the follow-up sample, the respective figures were 16 and 48. Thus 21% of the main sample, and 23% of the follow-up sample classified themselves as having a current injury by doctor’s diagnosis. As is shown in Section 3.3, this number includes individuals whose injury had occurred months or years previously but which nonetheless still affected them currently.

While the follow-up sample was relatively small, we are confident that it is representative, because where the identical comparisons could be made for the larger main sample and the follow-up sample, very similar outcomes were noted. This was true, for example, in the overall WAI scores, presented next. Following this, we present a summary in Table 3.5 of the many dimensions on which the two groups were compared. They are grouped into the major areas of work tasks, work demands, work organisation and culture, and work environment.

3.2.3.1 WAI scores among older workers by injury status

In the main sample (Sample 1), older miners (> 45) reporting no current injuries diagnosed by a doctor had a significantly higher (p < 0.001) mean WAI score than those reporting one or more current diagnosed injuries (refer to Figure 3.14). These results were echoed in the second, smaller sample.
In Sample 1, workers 45 or over who reported no doctor-diagnosed injuries had a mean WAI score of 42.5, while those who reported current injuries were significantly lower at a mean of 36.3. This 6-point difference is equivalent to 10.2 years age-related decline observed in the Finnish longitudinal studies (in which the WAI of older workers declined by an average 0.6 points per year). That is, the experience of injury would seem to affect work ability on a scale equivalent to a decade of ageing.

In the second, smaller sample (Sample 2), the difference between the mean WAI scores of injury-free (43.6) and injured (36.6) older miners was also highly significant (p < 0.001), equating to an 11.7-year decline in work ability.

3.2.3.2 Duration, frequency and physical demands of selected tasks

On the follow-up survey, additional detail was obtained about the 12 tasks/activities performed in coal mining outlined in the preceding section. Specifically, miners were asked to rate — across their whole career in the industry — the duration, frequency, and physical demands of each.

Duration was measured as the number of years the task was performed; frequency was the proportion (from 0% to 100%) of a typical work shift in
which they performed the task; while the physical demands of the task were rated from *low* to *extreme*. Both the latter were reported by marking a position on a visual analogue scale.

As an overview, the direction of differences is presented in Table 3.5, with significant differences ($p < 0.05$) shown in red. A more detailed depiction of the scores for each of the significantly different items is then presented in the form of a series of box-plots comparing the two groups.

**TABLE 3.5** Differences between injured and injury-free miners in ratings of duration, frequency and physical demands of selected tasks (workers 45+ only) across whole career

<table>
<thead>
<tr>
<th>CLASSIFICATION OF WORK DEMANDS</th>
<th>Duration</th>
<th>Frequency</th>
<th>Rating of physical demands</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MANUAL HANDLING</strong></td>
<td>Injured &gt; Injury free ns*</td>
<td>Injured &gt; Injury free ns</td>
<td>Injured &gt; Injury free (p &lt; 0.001)</td>
</tr>
<tr>
<td><strong>PUSHING, PULLING, DRAGGING</strong></td>
<td>Injured = Injury free ns</td>
<td>Injured &gt; Injury free (p &lt; 0.05)</td>
<td>Injured &gt; Injury free (p &lt; 0.002)</td>
</tr>
<tr>
<td><strong>REACHING FORWARD, BENDING, TWISTING, STOOPING</strong></td>
<td>Injured = Injury free ns</td>
<td>Injured &gt; Injury free (p &lt; 0.02)</td>
<td>Injured &gt; Injury free (p &lt; 0.006)</td>
</tr>
<tr>
<td><strong>APPLYING HIGH FORCES</strong></td>
<td>Injured &lt; Injury free ns</td>
<td>Injured &gt; Injury free ns</td>
<td>Injured &gt; Injury free ns</td>
</tr>
<tr>
<td><strong>PROLONGED WORK IN AN AWKWARD OR UNCOMFORTABLE POSTURE</strong></td>
<td>Injured &lt; Injury free ns</td>
<td>Injured &gt; Injury free ns</td>
<td>Injured &gt; Injury free (p = 0.02)</td>
</tr>
<tr>
<td><strong>DRIVING VEHICLES</strong></td>
<td>Injured &gt; Injury free ns</td>
<td>Injured &lt; Injury free ns</td>
<td>Injured &lt; Injury free ns</td>
</tr>
<tr>
<td><strong>OPERATING MACHINERY (OTHER THAN VEHICLES)</strong></td>
<td>Injured &gt; Injury free ns</td>
<td>Injured &lt; Injury free ns</td>
<td>Injured = Injury free ns</td>
</tr>
<tr>
<td><strong>SITTING</strong></td>
<td>Injured &lt; Injury free ns</td>
<td>Injured &lt; Injury free (p = 0.02)</td>
<td>Injured &lt; Injury free ns</td>
</tr>
<tr>
<td><strong>STANDING</strong></td>
<td>Injured &lt; Injury free ns</td>
<td>Injured &gt; Injury free (p &lt; 0.03)</td>
<td>Injured &gt; Injury free ns</td>
</tr>
<tr>
<td><strong>SHOVELLING</strong></td>
<td>Injured = Injury free ns</td>
<td>Injured &gt; Injury free ns</td>
<td>Injured &gt; Injury free (p = 0.006)</td>
</tr>
<tr>
<td><strong>REPETITIVE WORK (OTHER THAN THE PREVIOUS ACTIVITIES)</strong></td>
<td>Injured &gt; Injury free ns</td>
<td>Injured &gt; Injury free ns</td>
<td>Injured &gt; Injury free (p &lt; 0.04)</td>
</tr>
</tbody>
</table>

*ns = non-significant

In Table 3.5, several differences between older injured and injury-free miners are apparent. There was no statistically significant difference
between the two groups of miners in any task in terms of the reported duration (number of years) the task was performed.

For many of the physically demanding tasks, however, older miners with one or more current injuries rated their experience of the physical demands of the task, and the frequency in which they undertook these tasks, higher than their injury-free colleagues. Those tasks which older injured miners rated as significantly more physically demanding than older injury-free miners included:

- manual handling (e.g. lifting, carrying, lowering);
- pushing, pulling, dragging (e.g. cables, hoses, other loads);
- reaching forward, bending, twisting, stooping;
- prolonged work in an awkward or uncomfortable posture;
- shovelling; and
- repetitive physical work.

Older injured miners rated the frequency (proportion of a typical shift) with which they performed the following tasks significantly higher than older injury-free miners:

- pulling, dragging (e.g. cables, hoses, other loads);
- reaching forward, bending, twisting, stooping; and
- standing.

Conversely, injury-free miners reported spending more time sitting than injured miners of the equivalent older age group.

Long and arduous working conditions have been linked to an accelerated ageing process, greater risk of occupational strain injuries and the development of joint diseases (Calmels et al., 1998). In Finland, prolonged physically demanding work among men aged 42 to 65 has been associated with an increased risk (OR = 2.21) of early retirement on a disability pension (Karpansalo et al., 2002).

These results are consistent with the notion that greater exposure to demanding physical work is associated with higher rates of injury, a relationship that may very well be a causal one. The current study cannot be definitive on the question of cause and effect, however, since this requires a prospective study in which exposure is measured in a large population only and subsequent injury assessed. Such a study would allow clearer attribution of the occurrence of injury to the exposure. Our data shows only an association, so alternative interpretations are possible:

- that those who become injured have inherent factors that lead them to experience physical demands as higher and also predispose them to injury (for example, lower levels of work-related physical fitness); or
that those who are injured rate their work exposure differently from those who are not. It is always a possibility that being injured creates a more negative attitude to a range of work factors, which in a survey based on recall, are viewed in the light of that injury, even if those injured workers had no predisposition to injury and no actual differences in exposures.

At least two factors do not favour the second of these alternative interpretations, however. Firstly, the survey explicitly asked respondents to rate their exposure to the work factors over their entire working life in coal-mining. The time scale for this question is longer by three times than the average time since the current injury. If an injury alters a worker’s rating of exposure, then it would presumably have to do so for the whole working life, even the 2/3 of it that preceded the current injury. Secondly, if injured miners tend to over-estimate (consciously or otherwise) their ratings of exposure, it is unclear why they did not do so for any of the 12 items with respect to duration of exposure. Moreover, some items (such as “applying high forces”) were not rated significantly higher than by injury-free miners with respect to duration, frequency or physical demands. It is unclear why this would be the case if injury generally led to over-estimates of exposure to potential injury causes.

In Figure 3.16 (following), the mean, standard deviation, minimum and maximum ratings are presented as box-plots for the injured and injury-free miners for the items in which significant differences were found.

**FIGURE 3.16** Differences between injured and injury-free miners in ratings of duration, frequency and physical demands of selected tasks (workers 45+ only). Box-plots are shown only for those variables which differed significantly (p < 0.05) between groups.
Frequency of pushing/pulling/dragging

Physical demands of pushing/pulling/dragging

Frequency of reaching forward, bending, stooping, twisting

Physical demands of reaching forward, bending, stooping, twisting

Physical demands of prolonged work in awkward or uncomfortable posture
FIGURE 3.16 (continued)
Other studies have demonstrated the effect of physical work demands on work ability. A study of 1485 Polish workers in various occupations found that those who worked in painful or tiring positions, or were required to move or carry heavy loads, had significantly lower WAI scores than other workers not exposed to these physical demands (Bugajska et al., 2005).
### 3.2.3.3. Work environment and physical factors

Respondents were also asked to rate how often (across their entire career in the coal-mining industry) on a scale of *never* to *always*, they had experienced a number of environmental and physical conditions. Participants also rated the current controls in place for each of these conditions on a scale from *completely ineffective* to *completely effective*, which equated to points of 0 to 100. Table 3.6 summarises the results.

**Table 3.6** Differences between injured and injury-free miners in ratings of exposure to and effectiveness of current controls for work environment and physical factors (workers 45+ only) (ns = non-significant)

<table>
<thead>
<tr>
<th>WORK ENVIRONMENT AND PHYSICAL FACTORS</th>
<th>Exposure</th>
<th>Effectiveness of current controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXCESSIVELY HOT CONDITIONS</td>
<td>Injured &gt; Injury free (p &lt; 0.05)</td>
<td>Injured &lt; Injury free (p &lt; 0.05)</td>
</tr>
<tr>
<td>EXCESSIVELY COLD CONDITIONS</td>
<td>Injured &gt; Injury free (p &lt; 0.05)</td>
<td>Injured &lt; Injury free (p &lt; 0.05)</td>
</tr>
<tr>
<td>EXCESSIVELY POOR VISIBILITY</td>
<td>Injured &gt; Injury free (p &lt; 0.05)</td>
<td>Injured &lt; Injury free ns</td>
</tr>
<tr>
<td>EXCESSIVELY POOR ILLUMINATION</td>
<td>Injured &gt; Injury free (p &lt; 0.05)</td>
<td>Injured &lt; Injury free (p &lt; 0.02)</td>
</tr>
<tr>
<td>EXCESSIVELY LOUD NOISE</td>
<td>Injured &gt; Injury free ns</td>
<td>Injured &lt; Injury free ns</td>
</tr>
<tr>
<td>EXCESSIVELY UNEVEN GROUND</td>
<td>Injured &gt; Injury free (p &lt; 0.04)</td>
<td>Injured &lt; Injury free (p &lt; 0.02)</td>
</tr>
<tr>
<td>EXCESSIVE VIBRATION</td>
<td>Injured &gt; Injury free ns</td>
<td>Injured &lt; Injury free ns</td>
</tr>
<tr>
<td>EXCESSIVE ULTRAVIOLET (UV) EXPOSURE</td>
<td>Injured &lt; Injury free ns</td>
<td>Injured &lt; Injury free ns</td>
</tr>
<tr>
<td>EXCESSIVE COAL DUST</td>
<td>Injured &gt; Injury free ns</td>
<td>Injured &lt; Injury free (p &lt; 0.05)</td>
</tr>
<tr>
<td>EXCESSIVELY UNTIDY WORK ENVIRONMENT</td>
<td>Injured &gt; Injury free ns</td>
<td>Injured &lt; Injury free ns</td>
</tr>
<tr>
<td>EXCESSIVE FUMES OR GASES</td>
<td>Injured &gt; Injury free (p &lt; 0.03)</td>
<td>Injured &lt; Injury free ns</td>
</tr>
<tr>
<td>WET CONDITIONS</td>
<td>Injured &gt; Injury free (p &lt; 0.01)</td>
<td>Injured &lt; Injury free ns</td>
</tr>
<tr>
<td>POOR MATCH BETWEEN THE MACHINE, VEHICLE AND/OR EQUIPMENT AND BODY COMFORT OR MANOEUVRABILITY</td>
<td>Injured &gt; Injury free (p &lt; 0.02)</td>
<td>Injured &lt; Injury free (p = 0.02)</td>
</tr>
<tr>
<td>POOR ERGONOMIC CONDITIONS</td>
<td>Injured &gt; Injury free (p &lt; 0.01)</td>
<td>Injured &lt; Injury free ns</td>
</tr>
<tr>
<td>EXCESSIVE LEVELS OF ANY OTHER WORK ENVIRONMENT OR PHYSICAL FACTORS THAT HAVE IMPACTED ON YOUR WORK ABILITY OR RISK OF INJURY</td>
<td>Injured &gt; Injury free (p &lt; 0.001)</td>
<td>Injured &lt; Injury free (p &lt; 0.02)</td>
</tr>
</tbody>
</table>
Two separate issues arise from these results: degree of exposure and perceived effectiveness of controls. As with the preceding section concerning exposure to various tasks, injured miners over the age of 45 reported a greater level of exposure to a range of environmental factors that are potentially conducive to injury. Poor visibility, poor illumination, wet conditions, and uneven ground are characteristic of mining work but injured miners reported experiencing these adverse conditions significantly more. Excessive fumes and gases were also more often reported by these workers than by their injury-free colleagues. As with task exposure, it is not possible to verify these exposures with objective measures with this survey, and it cannot be ruled out that, again, the occurrence of an injury alters a miner’s perception of exposure, rather than the exposure itself being different. However, the findings raise the possibility that greater exposure to such conditions predisposes individuals to injury.

Ergonomic and design issues, including human-machine mismatches, were a second group of factors for which injured workers reported greater career exposures.

The second issue concerns the effectiveness of current controls. Once more, injured miners tended to rate a number of factors as being less well controlled than those who were not injured. This overlapped with, but was not identical to, those to which they had reported significantly greater exposure. For example, control over temperature conditions was considered significantly less effective by injured miners, but the same group did not report significantly greater exposure to excessively hot or cold conditions. Conversely, injured miners reported significantly greater exposure to poor visibility conditions, but did not rate controls for poor visibility as significantly less effective than non-injured miners. In the latter case, there may be a tendency to see some hazards as inherently less controllable than others.

Figure 3.17 provides a more detailed summary of the relevant ratings.

**FIGURE 3.17** Differences between injured and injury-free miners in ratings of exposure to and effectiveness of current controls for work environment and physical factors (workers 45+ only). Box-plots are shown only for those variables which differed significantly (p < 0.05) between groups.
Effectiveness of current controls for excessively uneven ground

Effectiveness of current controls for excessively hot conditions

Effectiveness of current controls for excessively cold conditions

How often miners experienced excessively poor visibility

How often miners experienced excessively poor illumination
These environmental and ergonomic factors are not easily controlled, but the current data support the need for continued efforts to improve environmental conditions and mining ergonomics. At the very least, older injured miners perceive their exposure to a number of these factors as more frequent than their injury-free colleagues, and/or rate the effectiveness of current controls lower.

### 3.2.3.4 Work organisation and culture

It is recognised that injury in the workplace has multifactorial causes. In addition to specific duties and tasks (which vary with respect to their demands and hazards) and over and above the work environment variables and ergonomic characteristics of work, the probability of injury may be affected by a range of work culture and work organisation factors.

To assess this, differences between the injured and injury-free groups of older miners provided ratings of a set of such factors, which are presented in the subsequent table and figure in the same way as for the preceding sections.

Table 3.7 provides a summary of those work organisation and culture issues that were rated differently by the two groups.

The most surprising outcome of this analysis was that, out of 18 factors, each of which was evaluated in two distinct ways (how often respondents experienced these factors, and how important they considered them to be), only three of the possible 36 different comparisons showed a significantly different rating by injured as opposed to injury-free miners. Specifically,
injured miners rated their enjoyment of work lower than injury-free colleagues, and were also less likely to rate the quality of mine management as excellent. The other significant difference was that injured miners considered “being listened to” as a more important factor than those without injury.

These differences are consistent with several possible interpretations, ranging from poorer and more critical attitudes on the part of injured miners, to the possibility that poorer mine management leads to less enjoyable work and a higher probability of injury. The former interpretation seems improbable, however, as there were many other opportunities for critical or negative attitudes to be expressed in this set of questions, and yet the large majority of them were not rated differently. For example, injured miners’ ratings of supervisor’s attitudes to health and safety, effective leadership, effective teamwork, whether they had worked in a productive environment, and whether they had been able to exercise reasonable control over their own work, were not significantly different from the miners who had not been injured. This strongly suggests that the factors that were rated differently represent specific views and experiences rather than any general tendency to be critical of conditions, supervisors or other aspects of work culture.
<table>
<thead>
<tr>
<th>WORK ORGANISATION AND CULTURE</th>
<th>How often miners experience these factors</th>
<th>How important miners believe these factors are/how important it is to prevent or control these factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEPUTY’S OR SUPERVISOR’S ATTITUDES TO HEALTH AND SAFETY HAVE BEEN EXCELLENT</td>
<td>Injured &lt; Injury free ns</td>
<td>Injured &gt; Injury free ns</td>
</tr>
<tr>
<td>EFFECTIVE LEADERSHIP</td>
<td>Injured &lt; Injury free ns</td>
<td>Injured &gt; Injury free ns</td>
</tr>
<tr>
<td>BEEN LISTENED TO</td>
<td>Injured &gt; Injury free ns</td>
<td>Injured &gt; Injury free (p &lt; 0.04) ns</td>
</tr>
<tr>
<td>CONSIDERED MINE MANAGEMENT TO BE EXCELLENT</td>
<td>Injured &lt; Injury free (p &lt; 0.04)</td>
<td>Injured &gt; Injury free ns</td>
</tr>
<tr>
<td>OPPORTUNITIES FOR CAREER DEVELOPMENT AT WORK</td>
<td>Injured &lt; Injury free ns</td>
<td>Injured &lt; Injury free ns</td>
</tr>
<tr>
<td>KNOWLEDGE AND EXPERIENCE BEEN UTILISED</td>
<td>Injured &lt; Injury free ns</td>
<td>Injured &gt; Injury free ns</td>
</tr>
<tr>
<td>FELT CONFIDENT AT WORK</td>
<td>Injured &gt; Injury free ns</td>
<td>Injured &gt; Injury free ns</td>
</tr>
<tr>
<td>MATES LOOKED OUT FOR YOU</td>
<td>Injured &gt; Injury free ns</td>
<td>Injured &gt; Injury free ns</td>
</tr>
<tr>
<td>EFFECTIVE TEAM WORK</td>
<td>Injured &gt; Injury free ns</td>
<td>Injured &gt; Injury free ns</td>
</tr>
<tr>
<td>WORKED IN A PRODUCTIVE TEAM ENVIRONMENT</td>
<td>Injured = Injury free ns</td>
<td>Injured &gt; Injury free ns</td>
</tr>
<tr>
<td>HAD GOOD RELATIONSHIPS WITH OTHERS AT WORK</td>
<td>Injured &gt; Injury free ns</td>
<td>Injured &gt; Injury free ns</td>
</tr>
<tr>
<td>ENJOYED YOUR WORK</td>
<td>Injured &lt; Injury free (p &lt; 0.02)</td>
<td>Injured = Injury free ns</td>
</tr>
<tr>
<td>JOBS HAVE BEEN MENTALLY STRESSFUL</td>
<td>Injured &lt; Injury free ns</td>
<td>Injured &gt; Injury free ns</td>
</tr>
<tr>
<td>JOBS HAVE BEEN MONOTONOUS (BORING, REPETITIVE)</td>
<td>Injured &gt; Injury free ns</td>
<td>Injured &gt; Injury free ns</td>
</tr>
<tr>
<td>HAVE BEEN EXHAUSTED AT WORK</td>
<td>Injured &lt; Injury free ns</td>
<td>Injured &gt; Injury free ns</td>
</tr>
<tr>
<td>HAD REASONABLE CONTROL OVER HOW YOU DO YOUR WORK</td>
<td>Injured &gt; Injury free ns</td>
<td>Injured &gt; Injury free ns</td>
</tr>
<tr>
<td>SUPERVISOR/DEPUTY ALLOCATED WORK FAIRLY</td>
<td>Injured &gt; Injury free ns</td>
<td>Injured &gt; Injury free ns</td>
</tr>
<tr>
<td>RECEIVED A SATISFACTORY LEVEL OF TRAINING CONSISTENT WITH YOUR WORK DEMANDS</td>
<td>Injured &gt; Injury free ns</td>
<td>Injured &gt; Injury free ns</td>
</tr>
</tbody>
</table>
Figure 3.18 provides descriptive statistics on the ratings for the three factors which were rated significantly differently by injured and non-injured miners.

![Box-plots showing differences in ratings](image)

**FIGURE 3.18** Differences between injured and injury-free miners in ratings of exposure to and effectiveness of current controls for work organisation and culture (workers 45+ only). Box-plots are shown only for those variables which differed significantly (p < 0.05) between groups.

It has been argued that at least some of the work-related psychosocial variables that can contribute to workplace stress and dissatisfaction are potentially amenable to change, for example through increased participation in decision making and problem solving (e.g. Michie & Williams, 2003).

### 3.2.3.5 Work and health

The final analysis in this section concerns broader issues of work and health, using the same approach as previously. Miners were asked to respond to a number of items related to work and health by rating how often they had
experienced each, and the extent to which that factor was present or available. The precise wording differed for each item. Table 3.8 shows that, as with the responses on work organisation and culture, only a minority of the items were rated differently.

Injured miners rated themselves as having had less adequate sleep over their working life in the coal-mining industry than their non-injured counterparts, and having kept less physically fit. They also were more likely to agree that their work involved aerobic and non-aerobic exercise and that they were too tired to engage in aerobic exercise outside work.

As with the other items, the interpretation of these responses is not clear cut, but the items on which the groups did not differ are once again revealing. Injured miners did not give significantly different responses on items related to nutrition, fluid intake, or coping with stress, for example. It therefore seems reasonable to attribute their responses on sleep and physical fitness as reflecting specific perceptions.

As with the three preceding groups of questions, those factors that distinguish older injured from older non-injured miners suggest areas where improved data collection and greater efforts to understand and modify the predisposing factors would be valuable.
**TABLE 3.8** Differences between injured and injury-free miners in ratings of work and health (workers 45+ only)

<table>
<thead>
<tr>
<th>WORK AND HEALTH How often miners have ...</th>
<th>WORK AND HEALTH</th>
<th>Level of agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>USED THEIR KNOWLEDGE OF HEALTH AND SAFETY PRACTICES</td>
<td>Injured &gt; Injury free ns</td>
<td>Knowledge and practices of health and safety are more directed towards safety than individual health promotion</td>
</tr>
<tr>
<td>BEEN ABLE TO COPE WITH MENTALLY STRESSFUL SITUATIONS</td>
<td>Injured &gt; Injury free ns</td>
<td>I have relied on my own rather than workplace resources to cope with work-related mental stress</td>
</tr>
<tr>
<td>HAD SUPPORT FROM THEIR SOCIAL NETWORKS OR FRIENDS</td>
<td>Injured &lt; Injury free ns</td>
<td>Opportunities for support contact or social networks are limited by your work arrangements</td>
</tr>
<tr>
<td>REGULARLY EATEN HEALTHY FOOD</td>
<td>Injured &lt; Injury free ns</td>
<td>Maintaining a healthy diet is severely limited as a function of your work arrangements</td>
</tr>
<tr>
<td>HAD SUFFICIENT FLUIDS THROUGHOUT THE DAY?</td>
<td>Injured &lt; Injury free ns</td>
<td>The value of drinking sufficient fluids and monitoring of fluids during a working day is well understood</td>
</tr>
<tr>
<td>HAD ADEQUATE SLEEP</td>
<td>Injured &lt; Injury free (p=0.03)</td>
<td>Roster and or travel arrangements make it difficult to obtain adequate sleep</td>
</tr>
<tr>
<td>REGULARLY KEPT PHYSICALLY FIT DURING LEISURE TIME</td>
<td>Injured &lt; Injury free (p&lt;0.03)</td>
<td>My work involves aerobic and non-aerobic exercise and I am too tired to do any more outside work</td>
</tr>
<tr>
<td>REGULARLY MAINTAINED OPTIMAL BODY WEIGHT</td>
<td>Injured &lt; Injury free ns</td>
<td>Maintaining optimal weight is difficult because of my current work arrangements</td>
</tr>
</tbody>
</table>
### WORK AND HEALTH

How often miners have ... | WORK AND HEALTH | Level of agreement
--- | --- | ---
| | Maintaining optimal weight is difficult because of my current work arrangements OR lack of knowledge about how to manage my weight | Injured < Injury free ns
| HAD EXERCISE PROGRAMS / EQUIPMENT AVAILABLE AT THE WORKPLACE | Injured > Injury free ns | Injured > Injury free (p < 0.05)
| WARMED UP MUSCLES OR STRETCHED BEFORE A SHIFT | Injured > Injury free ns | Injured > Injury free ns
| BEEN INVOLVED IN HOBBIES AND ACTIVITIES OTHER THAN SPORT | Injured = Injury free ns | Injured < Injury free ns

Figure 3.19 summarises the factors that were rated significantly differently by the injured and non-injured miners.

In terms of physical fitness, injured older workers reported significantly less physical activity outside work and less opportunity to do so than their injury-free colleagues. At the same time, they indicated they would be significantly more likely to participate in workplace physical activity programs. International studies have shown a strong correlation between physical fitness and work ability (Tuomi et al., 2004; Bugajska et al., 2005). The value of participation in well-designed and appropriate workplace programs has been demonstrated to improve, or at least prevent decline in, work ability (Tuomi et al., 1997; Smolander et al., 2000; Tuomi et al., 2004; Estryn-Behar et al., 2005). It has been argued, however that, especially for those involved in physically demanding work, such interventions should ideally begin before the onset of age-related deterioration of health and physical activity (Pohjonen & Ranta, 2001).
FIGURE 3.19 Differences between injured and injury-free miners in ratings of exposure to and effectiveness of current controls for work and health (workers 45+ only). Box-plots are shown only for those variables which differed significantly (p < 0.05) between groups.
3.2.4 Summary

This chapter reported on the match between individual work capacity and work demands, and the different experiences of injured and injury-free workers 45 and older across a range of work and health factors that may distinguish the two groups.

Overall, respondents predominantly rated their work ability as either “good” or “very good” in terms of both the physical and mental demands of work. Ratings in relation to the physical demands of work, however, decreased significantly across the four age groups. This was not the case for the mental demands of work which showed only a small decline in the oldest age group.

The work ability of professional/administration staff with respect to physical demands was significantly higher than for the trades or deputy categories. Electricians and mechanics/fitters rated their work ability with respect to the physical demands of work lower than those in the operator-maintainer/mineworker category. In addition, deputies and open-cut electricians reported lower work ability with respect to the mental demands of work than did other job categories.

These data, while suggesting a relatively high overall work ability with respect to physical and mental demands of work, also highlight the decline in work ability across the age groups for physical demands, and specific job categories in which work ability is less than optimal. The results confirm that the capacity for a mismatch between physical capacity and task requirements becomes more common with age. Measuring the requirements of work is challenging, and mental demands, in particular, are very difficult to quantify. In the case of deputies, the range of diverse duties and responsibilities may contribute to their somewhat lower scores on this dimension. However, these issues require more investigation, as the survey was not designed to probe them fully.

In line with one of the major goals of the study, this chapter reported on the differences between older miners who had remained injury-free and had retained high work ability, and those who had not. Firstly, and importantly, older miners (≥ 45) without injury had a significantly higher (p < 0.001) mean WAI score than those reporting one or more injuries. Based on previous longitudinal research, the injured group scores were equivalent to a decade’s decrease in work ability. The specific factors on which the two groups differed spanned the domains of work demands, work environment, work organisation and culture, and work and health.

Injured older workers reported significantly higher frequency of pushing, pulling or dragging; reaching, bending, twisting or stooping; more standing and less sitting across their working life than their injury-free colleagues.
Significant differences were also observed for a number of exposures in the work environment, with injured older workers reporting higher exposures to poor illumination and poor visibility, uneven ground, wet conditions and excessive fumes and gases. Poorer matches between man and machine, vehicles or equipment were also reported by the injured respondents.

Compared to their injury-free older colleagues, injured workers were less satisfied with the effectiveness of current controls for these exposures, as well as for coal dust and extremes of temperature. Injured workers were also significantly less likely to enjoy their work or to consider mine management to be excellent. They also placed higher importance on being listened to than those older workers who reported being injury free.

Regarding health factors, injured older workers were significantly less likely to report adequate sleep. They also reported lower levels of physical activity outside work and less opportunity to do so than their injury-free colleagues. On the other hand, they indicated they would be significantly more likely to participate in workplace physical activity programs.

Although the occurrence of injury could have led to injured workers forming a more negative outlook about work generally, and thus to a tendency to rate possible contributory factors less favourably, there was some evidence in favour of the more direct explanation that some of these features are associated with injury causation. There were several items which injured miners might have been expected to rate more negatively that received equivalent ratings from the two groups. This implies that they were making specific and selective judgments in this part of the survey.

These findings reinforce the association between injury and a range of working conditions many of which have been either implicated in injury causation anecdotally, or reported elsewhere. Injury is acknowledged to be a multifactorial phenomenon, and age is only one of many contributory factors. The fact that not all older miners experience injury demonstrates the importance of identifying the contributing personal, work and environmental factors, many of which can be better evaluated and controlled. The findings with respect to these differences underpin a number of the report’s recommendations.
3.3 INDIVIDUAL HEALTH FACTORS AND WORK ABILITY

The effects of age on work ability and the development of chronic diseases, such as diabetes, cardiovascular disease and musculoskeletal disorders are well established. Less is known, however, about the relationship between the type of work performed and the existence of medical conditions.

Self-rated health status, a component of the Work Ability Index, has been significantly associated with the decisions of middle-aged employees to remain in, or prematurely leave, the workforce (Lund & Borg, 1999; Karpansalo et al., 2004). This information has also been used to identify health issues which affect work ability, to provide targeted interventions to prevent further decline in work ability, and thus enhance the retention of older workers. Despite residual debate concerning its inherent subjectivity, the validity of self-rated health measures is widely accepted in occupational health outcomes research (Knauth et al., 2001; Cai & Kalb, 2005).

In large longitudinal studies, the WAI has been used to study occupational health and working life expectancy among workers of different ages (Nurminen et al., 2005). This type of study design is most useful when investigating changes over time, but is costly and not easily implemented in workplace settings. In cross-sectional studies, the average WAI of workers reporting one or more medical conditions has been shown to be significantly lower than those who said they were disease-free (Kiss et al., 2002). These relationships are complicated, however, by the fact that individuals have varying levels of functional capacity and experience different work demands. Because of this any particular medical condition will not necessarily have a consistent influence on work ability (Tuomi et al., 1997).

In 2002, the Australian mining industry recorded the highest incidence of work-related injury or illness of any industry, affecting more than 7000 workers or 8.8% of the total mining workforce (ABS, 2003).

In Queensland, a review of health surveillance in the mining industry identified musculoskeletal injury and psychological impairment as the major injury and illness challenges in Queensland (NRM, 2003). Almost 80% of workers’ compensation claims were for musculoskeletal injury, with psychological impairment the second most compensated condition, although accounting for less than 10% of all claims. As identified in the report, there is a need for easily applied and valid indices to measure impairment caused by these conditions. In terms of other health conditions, claims for respiratory and auditory conditions were very low compared to musculoskeletal injury and psychological impairment.

Ham (2003) analysed data from the Queensland Coal and Oil Shale (QCOS) Mining Industry Superannuation Fund, which provides benefits to the families of deceased members and to members with chronic disease conditions. Analyses of data for 1998-2002 showed that the most common cause of total permanent disability (TPD) among QCOS members was musculoskeletal disorder (MSD).
NSW Coal Mines Insurance (2005) data shows that the ratio of workplace injury to occupational disease claims for 2003-04 was roughly 90:10. Deafness is by far the most prevalent occupational disease claim, accounting for between 60% and 70% of all disease claims in the past three financial years.

It should be noted that NSW and QLD injury and disease surveillance methods are quite different, rendering meaningful comparison extremely difficult.

### 3.3.1 Reported medical conditions

This study focused on work ability and attempted neither a detailed examination of health within the coal-mining industry, nor any form of direct, objective health screening. The medical conditions listed in the survey were listed as items in the medical conditions section of the Work Ability Index and this self-report data was not confirmed by any other more objective measures of individual health status. Therefore the interpretation of the findings reported here requires caution, and should not be misinterpreted as being the equivalent of objective diagnosis. Nevertheless, the data do provide a common data set for a representative sample of the workforce, and show some patterns that may allow useful inferences about work and health to be drawn.

Respondents were asked to indicate (with a tick) any current medical conditions from the list included in the WAI, both by reference to their own opinion and if the condition had been diagnosed by a doctor. The number of reported conditions in each of the principal categories was the main quantitative measure used in all but the initial overview of major categories. It should be noted that no measure of severity was attached to these reports. Throughout this section, all data use the more conservative measure of reported doctor’s diagnosis of a condition, rather than own opinion. For two conditions, however, own opinion data is also reported because relatively large differences between the two indices were noted, possibly indicative of under-reporting.

Figure 3.20 depicts the frequency of reporting one or more medical conditions in each of the categories contained in the WAI. These categories broadly follow the headings used in the International Classification of Diseases. As some categories contained a larger number of specified conditions than others, it was necessary to obtain a measure for each that could be compared. To accomplish this, a respondent was classified as either reporting no conditions in that category, or one or more conditions in that category. The data presented are the proportions of the sample reporting one or more disorders. These values are shown for all categories in descending order of frequency in Figure 3.20.
As Figure 3.20 illustrates, 20.7% of miners reported one or more current injuries, while 17.7% indicated one or more musculoskeletal disorders (MSDs) that had been diagnosed by a doctor.

Injury in the Work Ability Index represents any current injury resulting from an accident. In contrast MSD is a more generic term involving a range of conditions affecting musculoskeletal and joint structures with the possibility of accompanying pain. Some MSDs may be caused by an injury from accident and in such instances there may be overlap in reporting between the two categories. It was the respondents’ interpretations of this information which was the basis for distinction between these medical conditions.

The next most commonly reported categories were respiratory conditions and sensory conditions. While respiratory diseases such as pneumoconiosis and silicosis have been serious medical conditions historically linked to mining, these specific conditions are not included in the Work Ability Index. Sensory conditions were reported by 10% of the workers, with hearing loss being the most prevalent problem.
Back injuries were the most commonly reported individual condition, followed by musculoskeletal disorders affecting the lower back. Upper back MSDs also ranked in the top eight. There is potentially overlap between the injury and MSD conditions as the survey did not allow any formal distinction between an injury and a musculoskeletal disorder. Eight per cent of miners reported problems or injury associated with hearing, and hypertension, which was the most frequently reported condition related to cardiovascular disease, affected a similar proportion of respondents.

The high reporting rate of the specific injuries in this study, and their patterns, are consistent with other studies of injury in mining. For example, back injuries have been found to be the most common site of injury of coal miners in the western United States (Madsen et al., 1998), accounting for the greatest number of lost work days in US mining due to injury (NIOSH, 2002). Similarly, a recent study of sprain and strain injuries in NSW and Queensland coal miners showed that the back, particularly the lower back, was the most common injury site (Parker et al., unpublished).

The relatively high numbers reporting hearing problems is consistent with the reported incidence of occupational hearing loss in the Australian coal-mining industry. Data from NSW indicate that more than 40% of the NSW coal-mining workforce had a compensable level of noise-induced hearing loss more than a decade ago (Leigh & Morgan, 1990; Worksafe, 1994). Despite efforts to control noise and the associated auditory damage, recent statistics indicate that deafness still accounts for between 60% and 75% of all occupational disease
claims (Coal Mines Insurance, 2005). Thus, it has been suggested that this issue needs to be given a higher priority within the industry (Farrar, 2001).

3.3.1.1 Reported medical conditions by age category, mine type and occupation

In addition to injury and musculoskeletal disorders, data for three other conditions pertinent to the coal-mining workforce will be presented in this report: cardiovascular, mental and sleep conditions.

In each of the cases presented below, the number of conditions reported as diagnosed by a doctor in each of the general categories served as the dependent measure. These were analysed by an ANOVA in which age category, mine type and job category were factors. Table 3.9 lists the medical conditions and the individual conditions chosen for this type of analysis.

**TABLE 3.9 Medical conditions analysed in this report**

<table>
<thead>
<tr>
<th>DETAILS OF MEDICAL CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injury from accident</td>
</tr>
<tr>
<td>• Back</td>
</tr>
<tr>
<td>• Leg/foot</td>
</tr>
<tr>
<td>• Arm/hand</td>
</tr>
<tr>
<td>• Other part of body</td>
</tr>
<tr>
<td>Musculoskeletal disorders (MSD)</td>
</tr>
<tr>
<td>• Conditions of the upper back or cervical spine</td>
</tr>
<tr>
<td>• Conditions of the lower back</td>
</tr>
<tr>
<td>• Sciatica: pain radiating from the back into the leg</td>
</tr>
<tr>
<td>• Musculoskeletal disorder affecting the arms, legs, hands or feet</td>
</tr>
<tr>
<td>• Arthritis</td>
</tr>
<tr>
<td>• Other musculoskeletal disorder</td>
</tr>
<tr>
<td>Cardiovascular conditions (CVC)</td>
</tr>
<tr>
<td>• Hypertension (high blood pressure)</td>
</tr>
<tr>
<td>• Coronary heart disease; chest pains during exercise (angina pectoris)</td>
</tr>
<tr>
<td>• Coronary thrombosis; myocardial infarction (heart attack)</td>
</tr>
<tr>
<td>• Cardiac insufficiency (heart failure)</td>
</tr>
<tr>
<td>• Other cardiovascular condition</td>
</tr>
<tr>
<td>Mental conditions</td>
</tr>
<tr>
<td>• Mental disorders or severe mental health problem (e.g. severe depression, mental disturbance)</td>
</tr>
<tr>
<td>• Slight mental disorder or problem (e.g. slight depression, tension, anxiety, mood changes)</td>
</tr>
<tr>
<td>Sleep problems</td>
</tr>
<tr>
<td>• Insomnia</td>
</tr>
<tr>
<td>• Sleep apnoea</td>
</tr>
</tbody>
</table>

3.3.2 Injury

Coal-mining is a risky industry and this is reflected in the high levels of injury, particularly musculoskeletal injury, reported by miners in this survey. Queensland workers’ compensation claims data (2002-2003) for the industry shows the top five conditions in terms of numbers of claims were sprains and strains; fractures; head injuries (including concussion); contusions and hearing loss (NRM, 2004d).
In New South Wales for the same period, compensation claims were made up of injuries to the back (21%), head/neck (18%), shoulder/arm (14%) hand/fingers (12%) and other injuries or conditions (37%) (Coal Services, 2003b). Sprains and strains accounted for 56% of all claims with 30% of all injuries attributed to overexertion.

In the current study, one-fifth of all respondents (21%) indicated that they had a current injury. Of these, almost half (48%) indicated the back as the region of the body most frequently involved followed by the leg/foot (31%) and the arm or hand (22%).

The number of reported injuries increased significantly across age groups from the 20’s to the 50’s, \( p < 0.05 \), with an approximately threefold increase from youngest to oldest age group (See Figure 3.22.)

![Graph showing frequency of reported current injuries by age group and mine type (mean ± 95% CI)](image)

**FIGURE 3.22** Frequency of reported current injuries by age group and mine type (mean ± 95% CI)

This increase in the number of injuries with age was roughly similar for both underground and open-cut operations; however, the reported injury rate was significantly higher for underground workers as a whole (\( p < 0.05 \)). The 30-39 and 40-49 years age groups were primarily responsible for the higher reporting levels of injury in the underground sector.

The finding of an increase in injury with age is consistent with previous research which has shown a higher incidence of sprain and strain injuries in older miners in Queensland and NSW from an analysis of injury data obtained from Coal Services and the Queensland Department of Natural Resources and Mines for the period 1996-2003 (Parker et al, unpublished). As workers become older, factors
such as stamina, flexibility, strength and maximal aerobic capacity decline (Ilmarinen, 2001). In many job categories in mining there remains a significant degree of physical work and for older workers, unless there is a reduction in the physical demands of the work relative to the decline in functional capacity, there is an increased risk of injury.

In contrast, findings from other industries suggest that older workers are injured less frequently than younger workers (Chau et al., 2004a; Salminen, 2004) although their injuries tend to be more severe and require a longer recovery period (Hull et al., 1996; McDonald & Harder, 2003; Gauchard, 2003; Pransky et al., 2005a). A major study of the health and safety needs of older workers in the United States also found that compared with younger workers, older workers experience lower rates of work-related injury, higher rates of injury severity, and longer duration of injury-related work absences (Wegman & McGee, 2004). These differences may reflect the nature of the work involved or the method of reporting of the injury data.

The finding of higher reported injury in older workers in the current study may in part be associated with the higher frequency of chronic or recurring injuries that characterise this group. The prevalence of age-related impairments in older workers has been identified as a likely contributor to increased injury risk (Wegman & McGee, 2004). While respondents were requested to identify current injuries, their response may relate to either an acute or chronic current injury. The precipitating injurious event may have occurred some time beforehand. An increase in injury reporting with age may in turn reflect the length of time in the industry. Given a greater amount of time in which to accumulate chronic injuries, older workers may report more chronic injuries than their younger, less-experienced counterparts.

This possibility was partially supported by the results of the second survey, which indicated that of those who reported a current injury, the mean time since the last injury was 5.2 years.

The somewhat higher number of reported injuries in underground mining operations is consistent with industry data, which suggests that the lost-time injury frequency rate (LTIFR) of underground workers was more than three times that of their open-cut colleagues in 2002-03 (Coal Services, 2003b). A recent study of sprain and strain injuries among Queensland and New South Wales coal mine employees showed that underground workers were four times more likely to suffer these types of injuries than their open-cut counterparts (Parker et al., unpublished report). While the current survey did not find the difference between the sectors to be nearly as large as these studies (30% for underground vs. 23% for open-cut), the apparent discrepancy may be easily resolved if it is also the case that underground miners tend to experience more serious injury. The frequency of reported injury will tend to differentiate the two sectors more if only more serious injuries are counted.
There was a significant difference in the rate of reported current injuries between job categories. As illustrated in Figure 3.23, professional/administrative staff reported significantly fewer injuries than three of the other categories: deputies (p < 0.001), operators-maintainers/mine workers (p < 0.001) and mechanics/fitters (p < 0.05). Underground mechanics/fitters reported the highest average rate of injuries of any job category, at more than twice the level of professional/administrative staff.

Comparable variations in injury risk among different job types have been reported in studies of other industries. In a study of 6854 US chemical industry workers, jobs involving heavy lifting were identified as presenting the strongest risk for occupational injury (Zwerling et al., 1996). Injury and type of job were also linked in a case-control study of 2610 French railway workers, which found that despite common risk factors such as inexperience, job dissatisfaction, sleep disorders and lack of physical activity, the role of risk factors varied with job type and working conditions (Chau et al., 2004b).

The relatively high levels of variance among the various job categories most likely reflects the broad range of duties associated with each category. For example, in the operator-maintainer/mine worker group some aspects of the work may require considerable physical effort, in contrast to other tasks such as driving or operating machinery, which are less physically demanding. In the current study, underground mechanics/fitters reported injuries at a higher frequency than other groups, but this was not the case for the open-cut miners.
in the same category, in which mechanics/fitters, deputies, and operator-maintainer/mine-worker values were quite similar.

The high values for underground mechanics/fitters likely reflect several factors, including the types of task involved in underground maintenance, in which machine components may be heavy, hard to access, and needing the application of high forces for installation or removal. Both handling hazards and the potential for crushing, bruising and laceration injuries are high. The same could be said for open-cut maintenance, however, so a likely additional factor is that the underground environment interacts with task type to increase injury likelihood disproportionately. Limited space, wet/muddy conditions, difficulty in using vehicles to bring heavy or awkward components to the optimal location, all make underground field maintenance extremely challenging. In the open-cut sector there is more opportunity to conduct workshop as opposed to field maintenance, and the use of vehicles and other machinery to assist field maintenance is less problematic. Compared to the less planned and routine tasks characteristic of field maintenance, normal production and development activities undertaken by operator-maintainer/mine workers are at least more predictable and therefore have benefited from a higher level of ergonomic and other injury control processes.

This injury category will also include a proportion of injuries which do not overlap with the musculoskeletal disorder category (following), including lacerations, contusions, and eye injuries. These are also likely to be more prominent in conditions favouring musculoskeletal disorder, as the same conditions will predispose towards loss of footing, slipping of tools, and uncontrolled contact with machinery, vehicles and other workers. Although this study was not designed to investigate the nature of injury, it is instructive to compare the data above with that in the following section, as it allows some distinction between these major classes of injury.

3.3.3 Musculoskeletal disorders

There are numerous clinical procedures used in the examination of musculoskeletal disorders with varying degrees of objectivity and validity, however more subjective methods such as worker self reporting are believed to contribute to an understanding of the impact of these disorders (Punnett & Wegman, 2004). The importance of cumulative exposure to MSD makes the accuracy and utility of self-reporting difficult to determine, however. Improved methods for assessing exposure are therefore necessary in order to inform strategies to reduce risk in the workplace.

Almost one-fifth (17.7%) of all respondents in the main sample reported one or more MSDs diagnosed by a doctor. Not surprisingly, the lower back was the predominant body region associated with reports of MSD. Of those with a MSD, almost one-third (32%) reported an MSD to the lower back and almost one-quarter (23%) an MSD to the upper back or neck (see Figure 3.21 above).
Significant age effects were found for the number of reported MSDs (p < 0.05), with a more than fourfold increase in the reporting of these conditions from the 20s to the 50s age groups in the open-cut sector, and a more than threefold increase from the 20s to the 40s in the underground sector, in which the small decline from the 40s to the 50s was not statistically significant (p > 0.05) (see Figure 3.24). There were no significant differences between mine types or job categories.

FIGURE 3.24 Frequency of reported musculoskeletal disorders by age group and mine type (mean ± 95% CI)

The presence of musculoskeletal disorders (MSDs) among workers in physically demanding occupations is common and these conditions (particularly low back pain) are the predominant contributor to work-related disability in the industrialised world (Krause et al., 2001). Among UK industries, mining accounts for the highest rate of annual reported MSDs (Cherry et al., 2001).

The cumulative nature of many musculoskeletal disorders suggests that older workers may be at greater risk due to their increased exposure to the physically demanding tasks associated with coal mining (Wiehagen & Turin, 2004). Unfortunately the common perception that physically demanding work will maintain and enhance fitness and provide a preventive outcome does not always apply (Punakallio, 2003). The intermittent nature of work in mining may not be sufficient to enhance aerobic capacity, mobility and strength and compensate for the age related changes in these measures. Consequently, physical work, particularly manual handling, may expose older workers with reduced physical
capacity to overexertion injuries and cumulative damage to the musculoskeletal system (de Zwart et al., 1995).

Figure 3.25 shows the pattern of reported musculoskeletal disorders by job type for the two sectors. It will be noted first that there were very high variances within groups in this analysis, such that there was no significant difference between any of the job categories (p > 0.05). Nevertheless, a surprising outcome was that the deputies in both sectors reported musculoskeletal disorders more frequently than the other groups. No explanation for this is immediately evident, as they report, for example, less repetitive physical work than mechanics/fitters in either sector, or underground operator-maintainer/mine workers, each of which report higher levels of repetitive physical work. Deputies were older on average than other workers, however, and may have accumulated more musculoskeletal damage. An additional possibility is that deputies contribute to physically demanding tasks when crew levels are low or in particularly challenging situations, and they could be at higher risk because they are somewhat less accustomed to this work than other members of the crew.

One follow-up study of ageing workers showed that among those who had remained in physically demanding occupations, the prevalence of MSD doubled from the age of 51 to 62 years (Seitsamo & Klockars, 1997; cited in Ilmarinen, 2002). The presence of MSDs among older workers have been found to be the most common health grounds for early retirement in Finland (Karpansalo et al., 2002; Salonen et al., 2003). Studies of industrial workforces in both China and
Italy have found significant associations between the presence of MSD and low scores on the WAI (Yang et al., 2004a; Capanni et al., 2005). Compared to other medical conditions, the presence of MSD had the greatest negative effect on WAI in a study of Belgian firefighters (Kiss et al., 2002).

3.4.4. Cardiovascular conditions

Cardiovascular diseases (heart, stroke and blood vessel diseases) are Australia’s largest health problem and biggest killer, accounting for more than one in three Australian deaths in 2002 (Heart Foundation, 2004). The mining workforce reflects the national picture with a significant number with cardiovascular disorders and an array of cardiovascular risk factors such as hypertension, overweight and poor lifestyle behaviours. In this sample approximately 8% reported a cardiovascular condition diagnosed by a doctor.

Hypertension (high blood pressure) was the most commonly reported cardiovascular risk factor among study participants with 7.6% of those reporting a cardiovascular problem also indicating having hypertension (see Figures 3.20 and 3.21 above).

![Graph showing frequency of reported cardiovascular conditions by age group and mine type (mean ± 95% CI)](image)

**FIGURE 3.26 Frequency of reported cardiovascular conditions by age group and mine type (mean ± 95% CI)**

Consistent with national population data, there is a clear effect of age group on the reports of cardiovascular conditions (CVCs) with workers in their 50s reporting more than 10 times the rate of CVCs than those in their 20s (p < 0.001). On average, open-cut workers reported more CVCs than their underground counterparts, but the difference was not significant. However, in
the largest job category (operator-maintainer/mine worker), open-cut workers had approximately twice the rate of CVCs, which are significantly higher than for underground workers in this category \( (p < 0.05) \). This result should be seen in light of the greater levels of sitting and lower levels of all forms of physical work reported by open-cut workers in this category presented in earlier sections. This implies a link between physical inactivity at work and the presence of cardiovascular conditions that may very well be causal.

![Frequency of reported cardiovascular conditions by job category and mine type (mean ± 95% CI)](image)

**FIGURE 3.27** Frequency of reported cardiovascular conditions by job category and mine type (mean ± 95% CI)

Underground professional/administration staff, followed by open-cut operator-maintainers/mine workers and deputies reported the highest number of cardiovascular conditions. Conversely, underground mechanics/fitters, electricians and operator-maintainers/mine workers reported these conditions the least (see Figure 3.27). These differences may reflect variance between the groups in age, nature of the work involved and/or differences in the health-related behaviours of the groups. In some cases, though, age is not the key factor. For example, underground deputies are significantly older (by an average of 6.8 years) than underground professional/administrative staff \( (p < 0.05) \), yet report fewer CVCs. In this context, it is noteworthy that underground deputies reported walking often (required for statutory inspections) more than any other of the nine sector/job category groups, and significantly more often than open-cut professional/administrative staff. This may exert a protective effect with respect to CVCs. Although professional staff have more sedentary work than some of the more physically active groups, opportunities for this group to engage in additional fitness-related activities outside of work may mitigate this effect.
The high prevalence of cardiovascular disease in the mining industry is not a recent phenomenon. In the 1980s, it was observed that mortality rates from ischaemic heart disease in the Hunter Region of NSW were among the highest in Australia, with the coal-mining district of Cessnock having the highest rates in the region (Alexander et al., 1986). Levels of overweight and obesity were shown to largely parallel the pattern of heart disease mortality. More recently, Australian coal-mining industry employees were reported to have higher levels of hypertension and obesity (both risk factors for cardiovascular disease) than the general population (Bofinger & Ham, 2002).

Studies conducted among other working populations suggest that workplace factors have a role to play in cardiovascular risk. For example, a longitudinal study of the role of work in cardiovascular mortality among Finnish workers, found that exposure to diesel exhaust, high workload, noise and irregular working hours (all factors associated with coal mining) increased the risk of cardiovascular disease and myocardial infarction (Virtanen & Notkola, 2002). For all causes of cardiovascular disease studied, workload had the most influence, followed by shift work and diesel exhaust (Virtanen & Notkola, 2002). The negative influence of shiftwork on cardiovascular health has been confirmed in other studies (Holmes, 2001; Knuttson, 2003).

A number of international studies of working populations have shown significant associations between high job demands, low job control and elevation of cardiovascular risk factors such as cholesterol, homocystine and triglyceride levels (Kang et al., 2005) hypertension (Cesana et al., 2003), presence of coronary artery disease (Kuper & Marmot, 2003) and myocardial infarction (Peter et al., 2002; Malinauskiene et al., 2004).

While previous findings suggest a close relationship between work-related factors and cardiovascular disease, it is also well known that lifestyle factors such as inactivity and poor dietary behaviours can increase the risk of CV disease. Lack of attention to these lifestyle factors is indicated in the weight of individuals, with overweight being established as a key indicator of hypertension and coronary artery disease (AIHW, 2002; Heart Foundation, 2004).

In this survey, 6.5% of the sample indicated that they had been diagnosed as overweight by a doctor (see Figure 3.21). In addition, using self-reported estimates of height and weight, the average body mass index (BMI) was calculated and was 27.5 for the study sample. The BMI is a simple and widely used method of estimating body composition using the formula: weight in kg/height in metres squared (kg/m²). By reference to the World Health Organization (WHO) categories for weight status (Table 3.10) the average BMI of 27.5 for this sample was in the overweight category. Figure 3.28 depicts the BMI by job category and mine sector.
### TABLE 3.10 WHO BMI categories

<table>
<thead>
<tr>
<th>BMI</th>
<th>Weight Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 18.5</td>
<td>Underweight</td>
</tr>
<tr>
<td>20-25</td>
<td>Normal</td>
</tr>
<tr>
<td>25.0 - 29.9</td>
<td>Overweight</td>
</tr>
<tr>
<td>30.0 and above</td>
<td>Obese</td>
</tr>
<tr>
<td>Above 40</td>
<td>Very obese</td>
</tr>
</tbody>
</table>

Source: WHO Nutrition and Food Security: Body Mass Index (BMI)
http://www.euro.who.int/nutrition/20030507_1

Although there is a possible contribution of a population bias — in that the mining workforce may include a disproportionate number of individuals with high levels of muscle mass relative to height — this nevertheless indicates that overweight is the norm among coal-mining employees. This finding is consistent with earlier information indicating that Australian coal miners of all age groups are disproportionately overweight compared with the general population (Bofinger & Ham, 2002). The average BMI of the current sample is the same (27.5) as that reported among a sample of underground metalliferous miners in north Queensland (Brake & Bates, 2003).

![Figure 3.28](image_url)

**FIGURE 3.28 Body Mass Index by job category and mine type (mean ± 95% CI)**

Overweight and obesity have been shown to be associated with decreased work ability (Tuomi et al., 2001; Estryn-Behar et al., 2004). A follow-up study of more
than 1000 Finnish municipal workers aged 55 to 62 found overweight to be strongly associated (p > 0.01) with reduced work ability after adjusting for gender, age and work content (Tuomi et al., 2001). Similarly, a high BMI was associated with lower work ability in more than 4000 French health care workers (Estryn-Behar et al., 2004).

While overweight is closely associated with lifestyle factors such as inactivity and poor nutrition, work factors such as shiftwork and long and irregular work hours may be involved. For example, a cross-sectional study of the influence of work characteristics on BMI among more than 6000 Japanese employees (mean age 39.2) found shiftwork to be significantly associated with higher BMI (Ishizaki et al., 2004).

Overweight also has been associated with increased risk of occupational injury (Zwerling, 1996; Bhattacherjee et al., 2003; Chau et al., 2003), while obesity is considered a contributory factor to knee injuries and osteoarthritis (Davis et al., 1989; Jensen & Rofail, 1999; Lau et al., 2000; Coggan et al., 2000). A statistically significant relationship also has been shown between obesity and carpal tunnel syndrome (Lam & Thurston, 1998; Becker et al., 2002).

In a case-control study of 854 French railway workers (mean age 41.4), overweight was the most predictive factor (OR = 2.07) for lengthy sick leave among injured workers (Gauchard et al., 2003). Chau and colleagues (2004) also found a strong association between sick leave of 8 or more days and overweight among a similar study population. Among industrial workers with low-back pain, Morken et al. (2003) identified that those who were overweight had an increased risk of long-term sick leave.

These findings suggest that workplace health promotion activities targeting weight control could contribute to the prevention of overweight and obesity, which may in turn help to reduce the risk of some musculoskeletal disorders.

3.3.5 Mental conditions

Mental health is an important component in the Work Ability Index. The presence of mental health problems in the workplace may have serious consequences, not only for the individual, but for the productivity of the enterprise. Employee performance, rates of illness and absenteeism, accidents and staff turnover are each affected by the mental health status of employees (WHO/ILO, 2000). A large US study of the economic impact for employers of chronic health conditions among workers found that depression, anxiety or emotional disorders more than doubled the risk of absenteeism (Collins et al., 2005).

As mentioned previously, psychological impairment has been identified as second only to musculoskeletal injury as a health issue in the Queensland mining industry (Lyne, 2003; NRM, 2003).

Almost 3% of respondents in this study reported having one or more mental conditions diagnosed by a doctor. Slight mental disorders or problems (e.g.,
slight depression, tension, anxiety or mood changes) were just over three times more common than severe mental health problems (such as severe depression or mental disturbance). Data from the NSW coal-mining industry suggest that anxiety or neuroses accounted for between 3% and 6% of all occupational disease claims in the last three financial years (Coal Mines Insurance, 2005).

The analysis of reported mental conditions diagnosed by a doctor in this study showed a significant increase (p < 0.05) in the number of conditions with age (see Figure 3.29). Neither mine type nor job categories differed significantly in the rate of reporting of mental conditions, as there were high within-group variances (see Figure 3.30). There was a significant interaction between sector and age group, however, (p < 0.05), with open-cut miners having a slightly higher prevalence of reported mental conditions in the younger age groups but somewhat less than the underground sector in the older age groups.

A further analysis was carried out, in which both criteria for reporting a mental condition (‘doctor’s diagnosis’ and ‘own opinion’) were included. (The data are shown in Figures 3.29 and 3.30). Overall, approximately three times more mental conditions were reported by miners in their own-opinion than were reported to have been diagnosed by a doctor, and this was statistically significant (p < 0.001). This suggests a possible underreporting of mental health conditions, a possible reason for this being the sensitivity involved with reporting this type of information. It may also indicate that workers may recognise changes in their mental status but did not believe these changes to be at a point where medical confirmation and/or treatment are warranted.

![Figure 3.29](image-url)

*FIGURE 3.29 Frequency of reported mental conditions by age group and mine type (mean ± 95% CI). Frequencies for conditions reported as diagnosed by a doctor and own opinion shown separately.*
Although the average rates shown by some job categories for ‘own opinion’ mental conditions in Figure 3.30 are quite different (e.g. underground deputies reporting more than double the rate of underground mechanics/fitters), the large within-group variances meant that these differences were not significant. Of more importance is that over 12.5% of the overall mining workforce reported that in their own opinion, they had a current mental condition. While in many instances this is likely to be minor, it is high enough to suggest further monitoring would be important.

**FIGURE 3.30** Frequency of reported mental conditions by job category and mine type (mean ± 95% CI). Frequencies for conditions reported as diagnosed by a doctor and own opinion shown separately.
3.3.6 Sleep problems

It is well documented that the relatively long working hours, shiftwork, and compressed rosters commonly found in 24-hour industries such as coal-mining are associated with reduced quantity and quality of sleep (e.g. Heiler et al., 2000; Ohayon et al., 2002; Sallinen et al., 2005; Folkard et al., 2005). As such, it was considered important to include questions in the survey instrument which relate to sleep disorders. While sleep disorders are not normally included in the Work Ability Index, it was considered that the small influence such inclusion would have on the WAI scores would be offset by the additional information in this important area.

Respondents were asked if they suffered from either insomnia or sleep apnoea. Insomnia, a symptom rather than a disease, is a common sleep complaint. Those who suffer from this sleep disorder regularly perceive sleep quality to be either inadequate or non-restorative (Rowley & Lorenzo, 2005). Insomnia is associated with a variety of complaints, including impaired ability to concentrate and increased risk of injury. For example, insomniacs are more than twice as likely as the general population to have a fatigue-related motor vehicle accident (Rowley & Lorenzo, 2005).

Sleep apnoea (or obstructive sleep apnoea syndrome) is a disorder characterised by episodes of partial or complete obstruction of the upper airway during sleep (Hartley et al., 1997). Research evidence suggests that people with sleep apnoea are at high risk for the development of hypertension (Lavie et al., 2000) and cardiovascular disease (Kiely & McNicholas, 2000).

Three per cent of respondents in the current survey reported a doctor’s diagnosis of either insomnia or sleep apnoea. Results from the ANOVA indicate a significant increase in these problems with age overall, (p < 0.05). There was an interaction between age category and mine type (p < 0.05). The two older underground age groups had rates of 6.8% and 8%, respectively, compared to open-cut values of 3.4% and 4.3%. Conversely, in the two younger age groups, the underground workers reported rates of 0% and 1.7%, compared with open-cut values of 0.7% and 4.6%, respectively. These effects are difficult to distinguish in Figure 3.31 because the small differences are of much lower magnitude than the corresponding “own opinion” values.

Further analysis of sleep disorders was also undertaken by examining the worker’s own opinion and the reported doctor’s diagnosis of a sleep disorder. Figures 3.31 and 3.32 include both sets of values.
FIGURE 3.31 Frequency of reported sleep problems by age group and mine type (mean ± 95% CI). Frequencies for conditions reported as diagnosed by a doctor and own opinion shown separately.

The significantly higher rate of “own opinion” sleep problems than those which had received a doctor’s diagnosis was statistically significant (p < 0.001). The effects of age were also very strong in the “own opinion” data: to the point that nearly one-third of open-cut workers in their fifties, and over one-half of underground miners in the same age group, reported a sleep problem “in their own opinion”.

This large difference between the rates using the different criteria may simply indicate that many of the sleep problems were of a minor nature, and not warranting medical consultation. However, it may also reflect true under-reporting and a possible lack of knowledge among the workforce of the acute and longer term significance of impaired sleep to health and work ability.

Although there are mean differences in the relative number of reported sleep disorders between job categories, these differences were not significant. However, as with mental conditions, electricians showed the greatest variation between mine types, reporting both the lowest (OC) and highest (UG) number of sleep problems diagnosed by a doctor. Professional/administration staff reported the fewest sleep problems by either criterion (Figure 3.32).
The finding of an increase in sleep disorders with age is consistent with previous research which has found an increased prevalence of both insomnia and sleep apnoea with age, and with shift workers (Akerstedt, 2002, 2003; Costa, 2005). Ageing is associated with changes in the ability to adjust to the circadian disruptions associated with work or sleep outside the normal patterns, as occurs with long distance travel and shiftwork. Older people also become more ‘morning oriented’, waking earlier and generally finding it increasingly difficult to sleep during the daytime period, which coincides with sleep periods for night shift workers. The generally lower tolerance to night work and the higher number of sleep-related disorders in this group has led to the more flexible work scheduling and elimination of night shifts for older workers adopted by some industries.

Insufficient sleep and impaired alertness are common problems of irregular working hours (Akerstedt et al., 2002b; Ohayon et al., 2002; Akerstedt et al., 2004; Sallinen et al., 2005; Rogers & Grunstein, 2005) and have also been associated with reduced work ability (Kloimuller et al., 2000).

Sleep disorders have been shown to be associated with increased risk of injury (Gauchard et al., 2003; Chau et al., 2004a), particularly injuries associated with physical exertion (Chau et al., 2004b). In those work environments where
sustained attention is necessary for safety, injury risk increases with the biological tendency to fall asleep (Hartley et al., 1997). The cost of sleepiness-related accidents in the United States has been estimated at US$16 billion per annum in reduced productivity and efficiency (Morshead, 2002).

Sleep disorders are a common cause of workplace fatigue. In a recent survey of occupational health and safety professionals in the Australian coal-mining industry, more than half (53%) of the respondents considered there was evidence that fatigue affected work performance at their mine site (Parker et al., 2004).

3.3.7 Estimated work impairment due to medical conditions

The results of a major study of ageing workers in the European Union (Ilmarinen, 1999) found that on average, one in five workers over 45 reported that their work was hindered by chronic diseases, ranging from 10% in Denmark and Sweden to 30% in Germany, Austria and Finland.

As indicated earlier, while a particular medical condition may influence work ability, the ability to function adequately and without risk of exacerbating the condition will depend on the functional capacity of the individual relative to the job demands and the ongoing support provided.

Chronic health conditions increase work absences, reduce productivity and represent a major economic burden on industry (Collins et al., 2005). The level of work impairment caused by chronic diseases was measured in a US cross-sectional survey of almost 8000 employees of Dow Chemical Company (Collins et al., 2005). Age, job type, the presence and number of chronic conditions, and hours worked were all significant (p = 0.001) factors associated with work impairment and significant predictors of absenteeism. Interestingly, the direction of the age effect changed for absenteeism, with those under 25 being twice as likely to take days off than those over 55, despite the latter group’s higher risk of disease (Collins et al., 2005).

In the current study, respondents were asked to estimate their level of work impairment as a result of any reported illnesses or injuries. Options were as follows:

- **It does not make it harder / I have no medical condition** (6)
- **I am able to do my job, but it causes me some symptoms** (5)
- **I must sometimes slow down my work pace or change my work methods** (4)
- **I must often slow down my work pace or change my work methods** (3)
- **Because of my medical condition, I feel I am able to do only part-time work** (2)
- **In my opinion, I am entirely unable to work** (1)

Mean responses ranged between “**It does not make it harder / I have no medical condition**” (score of 6) and “**I am able to do my job, but it causes me some
symptoms” (score of 5), i.e. the first two responses out of a possible six, down to being entirely unable to work (score of 1).

There was a strong overall effect of age ($p < 0.001$), (see Figure 3.33), but no difference between open-cut and underground employees. The significant effect for the job category variable was shown from the post-hoc analysis to stem entirely from the higher ratings (i.e. less effect of medical conditions) provided by professional/administrative staff compared to most of the other job categories. Professional/administration staff had estimated slightly less work impairment due to medical conditions than deputies/supervisors ($p < 0.001$), operator-maintainers/mine workers ($p < 0.001$) and mechanics/fitters ($p < 0.05$). See Figure 3.34 below.

**FIGURE 3.33** Estimated work impairment due to medical conditions by age group and mine type
Injuries and musculoskeletal disorders (MSDs) were the most frequently reported medical conditions, followed by respiratory, sensory and cardiovascular conditions. The back was reported as the major site of injury or MSD, while hearing loss was the major sensory condition.

One-fifth of all respondents reported one or more current injuries, with those in their 50s more than three times as likely to report a current injury as those in their 20s. The injury rate was significantly higher for underground workers, particularly those in their 30s and 40s, compared to their open-cut counterparts. There was also a significant difference between job categories, with underground mechanics/fitters reporting the highest average rate of injuries of all categories.

Musculoskeletal disorders were reported by almost one-fifth of respondents, with values for those in their 40s and 50s being three to four times more than those in their 20s. There were no significant differences between mine types or job categories for these conditions.

The higher frequency of injury with age is consistent with the findings from earlier research. For example, a retrospective longitudinal study (Laflamme et al., 1996) indicated that a substantial increase in injury can be presumed to result from more frequent accidents in older workers. The reduced physical
capacity to retain balance or to move out of the way of hazards is a major factor in accidents that disproportionately affect older workers. Hull et al. (1996) found that transport related activities, rather than equipment maintenance and metal/mechanical trades, accounted for the majority of severe coal mining injuries that predominantly involved the ageing workforce. In contrast, Hull et al. (1996) found that older miners did not show a significantly greater frequency in injury rates. However, injuries in older workers were more severe than in younger miners. The relationship between age and severity may be due to loss of durability, making older workers more susceptible to energy impacts encountered in underground mines.

Approximately 8% of respondents reported one or more diagnosed cardiovascular conditions (CVCs), with hypertension being the most common. Consistent with national population data, there was a clear effect of age, with workers in their 50s reporting more than 10 times the rate of CVCs than those in their 20s. While open-cut workers generally reported these conditions more frequently, the difference between mine types was not significant. Open-cut operator-maintainer/mine workers reported twice the rate of CVCs of their underground counterparts. This reflects the higher proportion of open-cut workers in this category, many of whom have more sedentary jobs such as driving. The same group reported significantly more sitting, and significantly less involvement in physically active roles.

Overweight was reported by 6.5% of respondents and the average Body Mass Index of 27.5 estimated from height and weight information, is considered in the overweight category by reference to World Health Organization guidelines.

Increasing the functional capacity of workers through complementary exercise programs is seen as a positive strategy to support older workers. Despite the relative lack of information about the older worker in coal-mining, there is a sound basis for paying special attention to health and fitness in the older age groups.

Almost 3% of respondents reported one or more mental conditions, with minor disorders such as tension and anxiety reported at three times the rate of more serious mental health conditions such as severe depression. There were significantly more mental conditions reported in the older age groups. Large within-group variances for this study factor meant no overall significant difference between job categories or mine types. The far higher rates of reporting mental conditions according to ‘own opinion’ rather than ‘doctor’s diagnosis’ suggests a possible under-reporting of these conditions.

Three per cent of respondents in the current survey reported a doctor’s diagnosis of either insomnia or sleep apnoea, with a significant increase across the four age groups. Underground workers in their 40s and 50s reported twice the rate of diagnosed sleep disorders as open-cut workers of the same age and the situation was reversed for younger workers. Sleep disorders are common in shift workers and older workers in particular have been shown to have lower tolerance to night shifts. Such disorders are commonly associated with acute disturbances to the digestive and cardiovascular systems. Such disorders may be exacerbated with
longer term sleep deprivation together with increased potential for fatigue, loss of alertness and heightened injury risk. Again, these conditions were reported much more frequently using the “own opinion” as opposed to the “doctor’s diagnosis” criterion.

Respondents were additionally asked to estimate their level of work impairment due to illnesses or injuries. Results exhibited a strong overall effect of age, but no difference between open-cut and underground employees. Professional/administrative staff reported significantly less impairment than most other job categories.

Overall, despite the fact that they could not be confirmed by objective diagnosis, the patterns of these reported medical conditions are consistent with previously described ageing effects in the workplace, and confirm the predominance of injury and musculoskeletal disorders in this population. The reported frequencies of both physically demanding and sedentary work broadly corresponded to the patterns of injury, MSDs and cardiovascular conditions reported by the different job categories. The report includes specific recommendations with regard to mental disorders and sleep problems, as the findings indicate possible under-reporting of these conditions.
RECOMMENDATIONS

The increasing age of the Australian coal-mining workforce presents challenges in the planning of work assignments for an older workforce. Modifications to the organisation of work, the work environment and the matching of work demands to the functional capacities of individual workers are essential to avoid the risk of higher injury rates, the exacerbation of work-related health problems and to promote the retention of workers and their associated skills and knowledge. Prior to the implementation of interventions, it is important to have the evidence base concerning the needs of the older worker and the influence of work and individual lifestyle behaviours on their ability to work without detriment to health. This study is the first in the coal-mining industry to focus specifically on the older worker and provides industry-specific information to assist the development of policy and strategies that meet the challenges of this demographic change.

The following recommendations are based on a number of information sources. While they are principally founded on the analysis of the current survey data, supporting information has been drawn from the occupational health literature, consultation with key stakeholders and comments from the survey respondents.

The recommendations should be considered in the context of the aims of the study and the purpose of the recommendations themselves. The study aims were to:

a) Determine the match between work demands and work ability in Australian coal mine employees of different ages;

b) Determine any differences in medically related factors that may impact on work ability and in relation to type of operation and occupational category; and

c) Characterise those older miners who have high levels of work ability and low rates of injury, in terms of work history, individual attributes and work patterns.

In framing the subsequent recommendations, it is recognised that any proposals for modifying policies and procedures in this area are potentially sensitive and can be seen in a quite different light by different sectors of the industry, i.e. unions, managers, supervisors, employers and regulators. Some of the recommended changes overlap with other processes, for example, the development of policy and legislation, collective bargaining, workforce planning, and recruitment. The following points should therefore be kept in mind when considering the recommendations. First, given the distributed responsibility for occupational health and safety, this report should be made widely available to all interested industry parties, because
the issues raised affect them in different ways. Second, improved systems for promoting the health and safety of older workers may carry with them the need to obtain and maintain more thorough and useful data about jobs and individuals. Some of this is inevitably somewhat sensitive, and careful consideration should be given to the ownership, use, storage of, and access to any new data that may follow from the implementation of any of the recommendations. Such arrangements involve factors outside the expertise of the research group, but we recognise, nevertheless, that they are central to the successful implementation of some of the recommendations. Improved health of older workers benefits the individual, the company, government and the community generally. New strategies to accomplish such reductions, and their implementation, must be no less a shared activity of all these parties.

The recommendations that follow are presented in five sections: health, work organisation, work environment, education and training, and research. This grouping reflects the fact that many recommendations apply to more than one topical area. In many cases, the recommendations involve strengthening and coordination of existing systems either within the industry or associated organisations.

HEALTH

1. **Review the current health surveillance practices within the mining industry with the aim of developing a more preventative and proactive approach to health management, consistent with the needs of older workers.**

The means by which Health Surveillance is conducted in the Australian coal-mining workforce has generated considerable debate and controversy. Unions and employers present varying points of view in areas such as the frequency and content of medicals and the practitioner designated to conduct them. While this debate continues, information provided by this and previous studies suggests that significant health problems exist and that new strategies are required to increase awareness of and, where possible, more successfully prevent these health problems at the individual and industry level. Additionally, examination of the appropriateness of existing health surveillance systems should continue in light of the major health issues prevalent in the industry and the changing demographics of the workforce.

**This recommendation is based on:**

a) Evidence from the study of:

- An increased prevalence of certain medical conditions with age and the significant relationship between these conditions and decreases in work ability;
- A threefold increase in the number of reported injuries from the 20’s to the 50’s age group, a fourfold increase over the same span for
musculoskeletal disorders, and a tenfold increase in the reporting of cardiovascular conditions;

- Evidence that specific job categories report high levels of injury (e.g. underground mechanics/fitters) and that this may be associated with the physical demands of work tasks;
- Evidence that specific job categories (e.g. open-cut operator-maintainer/mine-workers) report significantly more cardiovascular conditions than others and that this may be associated with the sedentary nature of their work; and
- Qualitative data indicating that health issues are considered important by workers in terms of enabling older miners to continue working safely and productively. Suggestions included enhanced screening for health problems through “more frequent medical examinations” and “regular health assessments”.

b) Extensive evidence in the research literature of age-related decrements in functional capacity such as aerobic capacity, strength, muscular endurance and flexibility (Shepherd, 1999).

c) Shortcomings in the existing health surveillance guidelines with respect to:

- the frequency of medicals being insufficient to properly monitor health and functional changes;
- the lack of specificity in terms of the relative risk of different occupational categories and increasing age (Parker et al., 2004);
- emphasis on absence of disease, rather than functional capacity in terms of fitness for duty; and
- incomplete information on contributors to poor health status, increased risk of injury and poor work ability status (such as sleep disorders).

_**Strategies to address this recommendation might include:**_

- The adoption of a ‘whole of working life’ approach to health surveillance, as illustrated in Figure 4.1. While the focus of this research is on the older worker, the ‘whole of working life’ approach requires that evaluation of health and functional capacity be ongoing and include the younger and middle-aged working groups. When individuals are in the final years of their career, specific longer-term health information, including exposure, be available. Health assessment of employees should occur at entry, periodically throughout working life, at critical junctures such as change of job or return to work following injury, and at exit from the industry. As previously stated, assessments on change of job are currently uncommon in mining. The ‘portability’ of health surveillance data throughout the industry is an important element of such an approach, so that on change of employment, this health information remains accessible.
**FIGURE 4.1 Model for a working life approach to health surveillance**

- Using a modified version of the WAI in conjunction with medical examinations to allow longitudinal data collection on the work ability of individual workers. This would also provide industry-wide knowledge of the work ability status of the workforce and for benchmarking with other industries. The WAI also provides a composite measure of health status, such as the number of medical conditions and their impact on individual work ability. The WAI has been shown to be a useful means of matching workers to appropriate jobs, as well as for monitoring functional capacity over time (Chan et al., 2000; Savinainen et al., 2004). Work ability should be monitored across working life, from pre-employment to post-retirement.

- Increasing the frequency of routine medical assessments for workers over 45 years. For older workers, a medical evaluation every two years is recommended.

- Miners should have the opportunity for seeking additional (i.e. non-scheduled) medical assessments of comparable depth and using the same evaluations, for the purpose of self-monitoring, informing health behaviour and lifestyle decisions, and decisions concerning work. Information from such additional assessments should be strictly confidential.
• Reviewing the content of medical examinations with a view to including:
  o More realistic and task-relevant measures of functional capacity and musculoskeletal function (including strength, flexibility and endurance) and which are sensitive to age-related changes in functional capacity; and
  o Extended monitoring of cardiovascular conditions and mental health in relation to physical and mental demands of position.

• Improving coordination between medical and other allied health professionals or OH&S specialists in terms of medical/health or functional capacity assessments.

2. It is recommended that medical assessments incorporate evaluation of psychological and sleep disorders.

This recommendation is based on:

a) Evidence from the study of:

• Reported diagnosis of either insomnia or sleep apnoea in 3% of respondents. Results also indicate that workers are experiencing more sleep problems than are being diagnosed, and possibly treated, by a doctor. This discrepancy and the number of sleep disorders increased with age;
• Older injured workers reporting poorer sleep over their careers in the industry than their non-injured counterparts;
• Almost 3% of respondents reporting having one or more mental conditions diagnosed by a doctor. This level of prevalence is in line with recent NSW Coal Mines Insurance (2005) data indicating that anxiety and neuroses accounted for between 3% and 6% of all occupational disease claims in the last three financial years;
• A significant increase in reported mental conditions with age; and
• In their own opinion, workers reporting three times more mental conditions compared to those diagnosed by a doctor suggesting a possible underreporting of these conditions.

b) Results of previous research indicating:

• An underestimation of the prevalence and impact of mental or psychological illnesses or disorders in the industry, with psychological impairment as the second most-compensated condition in Queensland coal mining (NRM, 2003);
• Contributors to poor health and injury, such as sleep and psychological disorders, may not be consistently ascertained by current medical examinations; and
• The significance of good mental health and sleep for safety both at work and in travel to and from work.
Strategies to address these issues might include:

- Reviewing the content of the current medical:
  
  o with respect to indicators of fatigue (such as sleep problems or lack of adjustment to shift work);
  
  o to include more detailed assessment of psychological problems with particular reference to the nature of the work and work organisation in which the worker is involved and evaluation of the psychological risk factors involved; and
  
  o raising awareness among medical assessors and those in supervisory roles of the nature and significance of mental and sleep disorders and their significance for the older worker.

3. **It is recommended that a more holistic approach to health care be implemented, including measures to promote work ability among older workers.**

There is strong evidence to indicate that work ability can be enhanced by improved fitness and that fitness is an important factor in the decision of workers to continue in the workforce. An increasing number of mining operators are implementing fitness and lifestyle change programs with varying degrees of success. While such programs may help prevent work-related illness or injury, a ‘one size fits all’ approach has limited value. Closer integration of such programs with periodic health surveillance will allow more targeted programs which may compensate for any deficits in functional capacity and provide a better match between functional capacity and work demands. Similarly, any program should be considered in relation to the work schedule of workers and the difficulties they experience in complying with the more traditional exercise routines. Physical activity should be effectively integrated into the work and home situation, and the quantity and quality of exercise that a person needs to derive health benefits and have the capacity to meet the demands of their work should be determined for each individual. In many industries, only a very small number of organisations effectively plan, implement, monitor and review the efficacy of these programs and there is a lack of accepted strategies to maintain and enhance the fitness levels of miners.

**This recommendation is based on:**

a) Findings from the survey indicating:

- High levels of self-reported overweight and an average BMI of 28;
- A high level of reported cardiovascular conditions in the workforce, which increases significantly with age (workers in their 50s reported more than 10 times the rate of CVD of those in their 20s, and double the rate of those in their 40s);
That injured older workers were significantly more likely than their injury-free colleagues to report that they were too tired to undertake exercise outside work;

That injured older workers reported that over their careers they had less often kept fit in their leisure time than their injury-free colleagues;

25% of the miners believed that health promotion was a key issue in enabling older miners to continue working safely and productively; and

That improving health and fitness was the third ranked suggestion by miners to reduce the risk of injury in the workforce.

b) Previous research indicating that:

- OH&S officers working in Queensland and New South Wales mines believed that lack of fitness and stamina rank highly as contributors to injury (Parker et al., 2004);

- Work in itself does not prevent a decline in work ability with age, particularly in physically demanding jobs (Ilmarinen, 2001). Nor does physically heavy work necessarily have a training effect (Savinainen et al., 2004);

- Work ability declines more rapidly in those workers who do not have the opportunity to engage in meaningful lifestyle activities nor have access to regular support of appropriately qualified health professionals (Ilmarinen et al., 1997);

- International studies demonstrating a positive correlation between physical fitness and WAI score (Tuomi et al., 2004; Bugajska et al., 2005);

- Overweight and obesity are associated with decreased work ability (Tuomi et al., 2001; Pohjonen, 2001; Estryn-Behar et al., 2005), increased risk of occupational injury (Bhattacherjee et al., 2003), the development of osteoarthritis (Davis et al., 1989; Jensen & Rofail, 1999; Lau et al., 2000; Coggan et al., 2000), more frequent and more lengthy sick leaves (Gauchard et al., 2003) and early exit from the workforce (Hopsu et al., 2005);

- In terms of cost-effectiveness, health promotion programs targeting older workers may result in greater decrements in preventable disease rates per unit of expenditure (Wegman & McGee, 2004); and

- Progression from poor to fair health status can increase the probability of workforce participation by about 30% (Cai & Kalb, 2005).

**Strategies to address this recommendation might include:**

- Health promotion activities which include preventive measures aimed at physical as well as psychological work demands and strain.

- Older workers in physically demanding jobs should be given the opportunity to enhance their fitness in relation to the demands of the job and with specialist guidance during work time.

- Appropriate dietary advice and exercise interventions should be implemented at the workplace or other appropriate venue to reduce the high level of overweight in the workforce and to improve levels of
physical fitness. These programs should be designed to suit work schedules and link to work/home models of lifestyle behaviour change.

- Any modification of lifestyle behaviour should be reflected in the outcomes from the regular health surveillance measures implemented.

4. **Review the extent to which current regulations provide protection to prevent morbidity in older workers and to protect those who stay in workforce.**

Industry policy makers must recognise that the mining workforce is ageing and will continue to age. This should be viewed positively with recognition of the older workforce as an important resource which has been shown in previous research to contribute extensive expertise, strong commitment, reliability, and fewer absences than their younger counterparts. However, to enable older workers to stay in the workforce there is often a need for greater flexibility, modification to work organisation and work content consistent with evidence of a lowered work ability and lower general health. Opportunities for re-training are also important.

Both Federal and State governments have increasingly recognised the issues associated with the ageing of the workforce and have implemented a number of policies designed to provide incentives for workers to work longer, including removing incentives to early retirement, banning of age discrimination, abolition of compulsory retirement. In addition, a range of strategies have been designed to raise awareness and support through training and other areas concerned with retention of older workers. While these initiatives are important, they are only the first step towards implementing new policy which will provide the safeguards in the workplace designed to protect the health of those who decide to continue working. For example, while policies concerned with age discrimination may be in place these policies provide no special rights for training, ergonomic redesign, and job/task modification for those with special needs. Many aspects of work life that are important for the careers of older workers and with implications for their health are not covered by legislation. These include factors such as length of working hours, reduced workload, overexposure to environmental hazards, and flexibility in work scheduling which are not usually addressed specifically for older workers. Such modifications are not always practical or cost effective and potential implementation will vary from industry to industry and site to site. Individual workers may also wish to retain the opportunity to work without any special modification even though they may be at greater risk of work-related injury or illness. Some of these adjustments to suit the older worker may also be possible within the current legislation and there are some examples of this within Australian industry.
This recommendation is based on:

The need for ‘age-sensitive’ policy change expressed in the results of this investigation and previous research on the older worker indicating that:

- Work ability decreases with age and that this is compounded by the higher number of medical disorders;
- Reductions in physical capacity with age increases the risk of injury and work related disease if the work is not modified consistent with these changes. This is particularly important for those in physically demanding jobs;
- Modifications to work organisation for older workers can increase the retention of older workers; and
- With the exception of age discrimination policies there is a general lack of specific policies related to the work of older workers.
- While anti-discrimination and OH&S legislation has been helpful in reconciling any differences in the position of employers and unions to accommodate those with a disability, successful accommodation of the older worker will require collaboration of employers and unions to initiate change (Freeman, 2004). This should be considered on the basis of scientific evidence and within a structural framework which recognises the need for engagement of a range of experts able to develop innovative and cost-effective approaches to job design and redesign, work organisation and work environment.

Strategies to address this recommendation might include:

- A review of existing strategies implemented or being considered in other industries or agencies including: roles for older staff, flexible work hours, job sharing and retraining for older workers. It is recognised that strategies will reflect the specific characteristics of each industry and a ‘one-size-fits-all’ approach is inappropriate. Initiating discussion with employees and raising awareness of issues facing the older worker will generate new strategies appropriate to specific situations.
- Review current OH&S policy to include age-sensitive guidelines designed, for example, to modify work organisation, work content, and the work environment according to the changing work ability of older workers.
- Any strategies designed to improve the retention rates of older workers should commence at the beginning of working life and involve younger workers. Any new policies designed to improve the conditions for older workers will also benefit other age categories.
- Enhancing existing industry data sources to include information on injury, illness or disorder rates according to demographic characteristics, particularly age:
  - Industry and union working party to consider features of health and injury databases that provide more useable and longer-term data while protecting privacy and ensuring only appropriate access;
Consideration by statutory authorities of their role in developing, regulating and oversight of new ‘age sensitive’ health and injury databases;

- Enhancing the comparability of databases by agreeing on core measures for use by different companies and in different jurisdictions.

- Determine, through evidence based research, standards for exposure to mechanical loading, length of working hours consistent with the age-related work ability of older workers and according to previous exposure to these conditions.

- Increase targeted training opportunities for older workers to upgrade skill levels.

WORK ORGANISATION

5. **Physical work demands (e.g. repetitive work, poor work postures, manual handling) should be reduced for older workers consistent with changes in functional capacity.**

An obvious and frequently stated strategy in the management of the older worker is to suggest that they reduce or eliminate any excessive physical demands in their work and adopt a mentoring or supervisory role. For some miners this will be most appropriate as the experience and extended knowledge base of many older workers enables them to play a very significant part in a range of supervisory and training activities. However, it is acknowledged that these types of opportunities may be limited to only a small number of those miners wishing to work longer and alternative strategies will be required. For those miners who cannot be accommodated with such alternative duties, controlling exposure to excessive physical demands becomes particularly important. A reduction in the physical demands of the work in these cases will only occur with recognition of the need to provide more flexible work arrangements. This could include a reduction in the number of hours worked, opportunities for part-time employment and a reorganisation of the content of work.

*This recommendation is based on:*

a) Evidence from the survey that:

- Mine workers in the older age categories, i.e. over 40 years, have significantly reduced work ability compared to their younger counterparts;
- Showed a clear and statistically significant decline across age categories for self-rated work ability with respect to the physical demands of work;
- Indicated significant differences between injured and injury-free older miners (45 yrs +) in terms of the perceived physical demands of work tasks;
- The modification of work tasks to better match abilities was the most common suggestion for assisting older miners to continue working safely and productively; e.g. “give them jobs suited to their age” or “give them...
jobs structured to suit their skill level”; and

- Miners believed older workers would benefit from decreased physical demands, improved work allocation and increased job rotation.

b) Evidence from previous research that:

- Only 27% of coal mines in a survey of OH&S practitioners indicated they had made special arrangements to accommodate older workers (Parker et al., 2004).
- Decreasing physical workload is the most significant factor in the promotion of work ability in older workers (Ilmarinen & Rantanen, 1999).
- Heterogeneity in functional capacity increases with age, suggesting that more individual and flexible solutions should be available to assist workers to manage their work.
- Older workers generally require increased time for recovery from physically demanding work.
- In a European survey on Working Conditions nearly 50% of older workers were exposed to repetitive work (Paoli, 2004). About 30% had poor work postures, while 15 - 20% were handling heavy loads at least 50% of their time at work.
- Older underground miners (in comparable job categories) do not always bear a reduced physical burden (Parker & Worthingham, 2004a).
- Older workers with decreasing functional capacity may be working closer to their limits, thus increasing the risks of injury. The National Occupational Health and Safety Commission (NOHSC, 2003) has recommended that where possible, work demands should be reduced to levels within the comfortable capacities of workers. Where this is not possible, levels of autonomy and control should be increased. This could be particularly beneficial for older workers, enabling them to adopt performance strategies to best suit their physical capacities.
- Reductions in musculoskeletal and cardiovascular capacity over time are more common among those with high workloads, suggesting that physical workload has more of a wearing than training effect (Savinainen et al., 2004).

**Strategies to address this recommendation might include:**

Consider and implement opportunities for:

- Effective workload distribution and monitoring strategies to reduce the physical work demands on older workers while allowing longer recovery periods;
- More flexible work arrangements for older workers;
- Increasing autonomy in work to control the pace of work and work demands;
- Reducing the duration of work in situations where it is difficult to reduce work demands;
6. **Review the shiftwork arrangements for older workers with respect to the reduction in excessively long hours, and with the aim of providing more flexible arrangements and the opportunity to avoid night work.**

**This recommendation is based on:**

Evidence from the current research indicating:

- A sevenfold increase in self-reported sleep disorders between the 20- and 50-year-old age groups, suggesting poor quality and duration of sleep.
- That in the opinion of miners, long working hours and night work are among the 3 most important factors that need to be modified to keep older workers longer in the workforce. They suggested that older workers should work reduced hours (“shorter daily hours - no 12-hour shifts”; “replace 12-hour shifts with 8-hour shifts”), preferably without night shift (“no night shift”; “day shift only”).
- Injured workers (45 yrs +) reported significantly less adequate sleep than their injury-free colleagues.

Evidence from previous research of:

- An association between shiftwork and increased risk of cardiovascular disease and myocardial infarction (Knutsson et al., 1999; Virtanen & Notkola, 2002; Ishizaki et al., 2004; Ha & Park, 2005).
- The lower tolerance of older workers to night work, through greater circadian disruption and increased difficulty in sleeping outside of normal sleep periods (Akerstedt, 2002, 2003; Costa, 2005).
- The greater predictive power of disturbed sleep patterns than either workload or lack of exercise in relation to fatigue (Akerstedt et al., 2004).
- Reducing working hours or making them more flexible is an effective measure to adjust both physical and mental work demands to individual working capacity (Knauth, 2005).
- The recognition that risk assessments of working hours must take account of the specific needs of older workers (Maher, 2001).

**Strategies to address this recommendation might include:**

- Implementation of more flexible work arrangements for older workers and opportunities to avoid night work in situations of low tolerance, and
in situations where there is evidence of sleep disorders or other conditions associated with or likely to be exacerbated by shiftwork; and

- A review of flexible work arrangements for older workers implemented in other industries.

**WORK ENVIRONMENT**

7. *Higher priority be given to the mitigation of harmful work environment variables, such as uneven ground, vibration, wet conditions, poor illumination, and poor ergonomics. Where complete mitigation is not possible, tighter exposure standards for older workers be developed.*

It is widely acknowledged that exposure to environmental factors that are potentially damaging to health should be carefully monitored and controlled, irrespective of the age of the worker. However, such control measures are not always fully implemented. The current findings reinforce the link between work environment variables and injury, and reinforce the priority of controlling them optimally. In addition, thresholds considered acceptable for younger workers may need modification for their older counterparts, consistent with their lower tolerance to such stressors as high temperatures, vibration and noise.

*This recommendation is based on:*

a) Findings from the current study indicating that:

- Among older workers (45 yrs+), those with a workplace injury reported greater exposure to work environment hazards (including fumes and gases, uneven ground, poor illumination and poor visibility, mismatch between machinery and body comfort, poor ergonomic conditions) than their injury-free colleagues.
- There were significant differences in the perceptions of injured and non-injured older workers in relation to the current controls for ameliorating the effects of excessive workplace heat and excessive dust. The injured workers believing that the controls were ineffective.
- Hearing problems were the third most commonly reported medical condition (after injury and musculoskeletal disorders of the back) by participants in the current study.

b) Evidence from previous research that:

- Age-related changes, whether pathologic or normative, can increase the susceptibility of older workers to environmental hazards (Wegman & McGee, 2004).
- Older workers are generally less tolerant to hot environments and dehydrate at a faster rate (Marszalek et al., 2005). In turn, dehydration can lead to a range of physical, mental and psychological decrements in work performance (Brake & Bates, 2003). Beyond the age of 45, workers
respond to work-heat stress with higher heart rates, slower heart rate recovery, higher skin and core temperatures, and lower sweat rates than their younger colleagues. These factors place added strain on the cardiovascular system. Men over 45 working in a hot environment have been shown to have higher physiological costs and lower work ability than younger workers (Marszalek et al., 2005).

- Recent NSW coal-mining statistics indicate that deafness has accounted for between 60% and 75% of all occupational disease claims since 2001-02 (Coal Mines Insurance, 2005).
- The prevalence rates of both hearing loss and persistent tinnitus increased both with age and according to years spent in noisy occupations (Palmer et al., 2002).

**Strategies to address this recommendation might include:**

- Reviewing the current requirements for noise-related standards in relation to the differential sensory changes that are found in older workers;
- Developing new measures to evaluate the work environment and standards with respect to the impact on the older worker in areas such as illumination in underground mining, and exposure to thermal stress;
- Improving the design and ergonomic characteristics of machinery with regard to the capacities of the older worker;
- Placing a high priority on maintenance of roadways and work surfaces; and
- Reviewing the current job design strategies and other work environment factors with regard to reductions in sensory acuity of the older worker.

8. It is recommended that methods to assess exposure to mechanical loading, awkward postures, and other risk factors for musculoskeletal injury are developed and evaluated.

The high incidence of musculoskeletal disorders in the Australian mining industry is associated with significant personal and corporate costs. Sprain and strain injuries account for more than 50% of all injuries in underground mining and a higher incidence of injury has been found in older workers.

Reducing the risk of injury requires the recognition of hazards and their associated risk. The relationship between risk factor exposures and the level of musculoskeletal injury is difficult to define. Additionally, factors other than physical risk factors, such as organisational and psychosocial issues may be associated with musculoskeletal disorder either directly or indirectly.

Monitoring the mechanical environment is limited by the lack of easily applied measures of workload and the impact of this load on related musculoskeletal disorders.
This recommendation is based on:

Evidence from the current study indicating that:

- There was a significant increase in the number of injuries and musculoskeletal disorders with age; and
- Older workers with injury reported poor ergonomic conditions throughout their career more often than their injury free counterparts.
- Older workers with injury rated the physical demands of their work across their working careers in mining higher than their injury free counterparts. This included exposure to manual handling, pushing pulling and dragging, prolonged work in awkward or uncomfortable postures and shovelling.

Strategies to address this recommendation might include:

- Reviewing guidelines from other countries associated with the older worker. For example, in the US, the National Research Council’s Committee on the Health and Safety Needs of Older Workers has recommended the development of new longitudinal data sets containing detailed information on workers’ employment history, the specific demands of their jobs, and the associated health and safety risks (Wegman & McGee, 2004). This would include levels of chemical, physical, biomechanical and psychosocial factors.
- Implementing clear guidelines for the identification of hazards and characterisation of exposures related to the mechanical and ergonomic demands of work with particular reference to the older worker.
- Developing a database which identifies the key biomechanical and ergonomic risks which may impact the health of older workers.
- Placing special emphasis on the assessment of exposure when individuals change position, or re-enter the workforce at an older age, as these individuals may be at heightened injury risk.
EDUCATION AND TRAINING

9. It is recommended that the industry implement training programs for managers and supervisors to raise their awareness of the issues facing older workers and to provide information on the principles and processes involved in managing the older worker.

There is a need to expel some of the myths commonly associated with the older worker such as being less productive, more rigid in their thinking and less worth the investment in training. Promotion of the more positive characteristic of the older worker, such as their commitment, reliability and the wealth of experience is fundamental to develop a sound respect for the contribution of the older worker and the role they play in ensuring the appropriate blend of youth and experience in the team situation. While at some levels of the workforce this recognition will occur as a function of the interactions which occur between individuals of different age, there remains a need for managers and supervisors in particular to understand the specific needs of older workers. Such appreciation and a sounder knowledge base will enable the development of new strategies designed to help those who wish to work longer to continue to do so without discrimination and with work conditions which are protective of their short and longer term physical and mental health.

This recommendation is based on evidence indicating that:

- The behaviour of superiors can have an immediate effect on maintaining or improving the work ability of ageing workers (Knauth et al., 2005);
- Age management has been described as “the most powerful tool” for improvement of work ability in older workers (Ilmarinen and Rantanen (1999: 22);
- A well-planned age management program can be a successful strategy for promoting the work ability of older workers, but lack of knowledge as to how ageing can affect work ability has been identified as a major obstacle to successful age management (Skoglund & Skoglund, 2005);
- In a survey of OHS officers in the mining industry only 17% of mines surveyed had processes in place to accommodate the older worker (Parker et al., 2004) and there was general lack of information in current policy and educational programs on issues concerned with the older worker;
- The significant amount of evidence indicating that older workers have a significant capacity for continued learning (Wegman & McGee, 2004); and
- Qualitative comments from workers in the survey indicating that training in specific tasks was important in helping older workers to stay in the workforce longer.
Strategies to address this recommendation might include:

- Raising awareness through relevant training, information and education programs of the principles and opportunities for supporting and retaining older workers.
- Providing opportunities for all levels of the workforce to better understand age-related issues and opportunities to support the older worker.

10. Enhance the awareness and training of medical personnel in detecting work-related medical problems of older workers.

Previous research has identified the need for improved training of medical personnel on industry specific issues in relation to the nature of mining work and the health risks associated with particular positions. Such training would enable them to make more informed decisions in areas of worker suitability for particular jobs and risk management with respect to prevention of work related injury and illness. These issues become even more important when faced with the prospect of an older worker returning to the workforce or deciding to work longer. Although there is limited evidence on the effect of longer term exposures to particular work conditions it is likely that the older worker across their working life will have experienced conditions which are conducive to chronic injury and illness. Consequently, inappropriate matching of the physical and mental demands of the job with the capacities of the individual is more likely to produce adverse health effects.

More accurate and realistic evaluation of medical and work-related health status will also be essential in this older population because of the increased possibility of litigation and compensation cases.

This recommendation is based on evidence that:

- Medicals do not specifically target level of risk associated with different positions, nor do they normally address altered risk following from a change of position or increased age (Parker et al., 2004).
- The higher potential for injury and work-related disorders in older workers as identified in this survey and previous research.
- The limited level of industry-specific knowledge among medical practitioners in relation to the specific tasks undertaken by different job categories, and the consequent risks, especially for older workers.

Strategies to address this recommendation might include:

- Industry/government-sponsored workshops to update training of medical personnel with respect to appropriate content, requirements, and qualifications;
- The development of web-based training materials to assist medical personnel working in isolated areas; and
• Development of continuing medical education resources on the older worker.

RESEARCH

11. It is recommended that the industry implement and support a research program designed to address key questions related to the ageing of the mining workforce.

In contrast to other countries such as Finland, Australia lags behind in research concerned with the impact of work on the biological, social and behavioural characteristics of older workers.

The US National Research Council’s Committee on the Health and Safety Needs of Older Workers has recommended a systematic research program to provide greater understanding of the effects of workplace exposures on older workers and the health implications of these exposures into retirement (Wegman & McGee, 2004). The Committee has further recommended a program of research to audit existing workplace health promotion programs and employee assistance interventions, and evaluate their effectiveness.

In mining, although there is increasing recognition of the issues facing the industry associated with this demographic shift there is little evidence upon which to base new interventions. It is important, therefore, that the industry develops and supports a research agenda in this area as the basis for improved management of the older worker and the potential benefits derived from a healthier and productive workforce. On the basis of the results of the current investigation, the following research areas are considered worthy of inclusion in this program:

• Support for research involving longitudinal analysis of work and retirement patterns in ageing cohorts and to enable evaluation of their effects on health.

• Support for research on ergonomic and biomechanical aspects of work in older miners, especially methods to assess exposure to biomechanical loading.

• Investigate how well the industry is reporting work-related injury and illness and identify any barriers to effective reporting.

• Investigate factors that influence work decisions associated with the interactions between work and the ageing process.

• Evaluation of the impact of contract labour on work ability, demographics, health and injury in older workers.
• An examination of the extent and efficacy of existing processes to assist older workers stay in the workforce.

• Implementation of epidemiological research in conjunction with medical assessment to provide data which could be used to build an ongoing picture of the health of the workforce, and form a basis for evaluating the efficacy of any health-related interventions.
APPENDIX 1

RESPONSES TO OPEN-ENDED QUESTION (Sample 1)

List the three most important things you believe would help older miners continue working safely and productively as long as they wish?

After completing the questionnaire, respondents were invited to offer further comments by listing the three most important things they believed could assist older miners to continue working safely and productively as long as they wish. As explained in the Methods section, responses were categorised according to what the comment primarily addressed, then specific topics were determined and the type (or direction) of suggested changes was coded.

The purpose of this open-ended question was to extract additional information from respondents relating to their perception of what determinants influence safety and productivity in the older miner.

For analysis purposes, the comments were divided into the major classification areas as represented in Table A.1, which includes the frequency of responses from a total 3335 (from 1624 Survey 1 respondents).

<table>
<thead>
<tr>
<th>Classification</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work tasks</td>
<td>654</td>
<td>19.6</td>
</tr>
<tr>
<td>Work organisation</td>
<td>630</td>
<td>18.9</td>
</tr>
<tr>
<td>Health</td>
<td>630</td>
<td>18.9</td>
</tr>
<tr>
<td>Training</td>
<td>294</td>
<td>8.8</td>
</tr>
<tr>
<td>Management</td>
<td>262</td>
<td>7.8</td>
</tr>
<tr>
<td>Safety</td>
<td>240</td>
<td>7.2</td>
</tr>
<tr>
<td>Ergonomics</td>
<td>224</td>
<td>6.7</td>
</tr>
<tr>
<td>Individual Issues</td>
<td>156</td>
<td>4.7</td>
</tr>
<tr>
<td>Finance</td>
<td>106</td>
<td>3.2</td>
</tr>
<tr>
<td>Social relationships</td>
<td>77</td>
<td>2.3</td>
</tr>
<tr>
<td>Irrelevant comments</td>
<td>62</td>
<td>1.9</td>
</tr>
<tr>
<td>Total</td>
<td>3335</td>
<td>100</td>
</tr>
</tbody>
</table>

As demonstrated, the main topics that emerged from the data were related to work tasks, work organisation and health, with other common but less frequent topics being training, management, safety and ergonomics. Only the broad areas with a response rate greater than 5% were analysed. For each of these primary categories, a number of common topics emerged. From these, specific details of any suggested changes were recorded.
MOST COMMON RESPONSES OVERALL

The most commonly reported comments across all survey respondents following analyses are shown in Table A.2. These responses represent 826 out of 3335 comments made, representing almost one-quarter (24.8%) of all responses.

TABLE A.2 Most common responses to open-ended question (Survey 1)

<table>
<thead>
<tr>
<th>Response</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decrease shift hours</td>
<td>264</td>
<td>7.9</td>
</tr>
<tr>
<td>Decrease physical demands of work</td>
<td>147</td>
<td>4.4</td>
</tr>
<tr>
<td>Trainer / supervisor roles</td>
<td>96</td>
<td>2.9</td>
</tr>
<tr>
<td>Increase job rotation</td>
<td>93</td>
<td>2.8</td>
</tr>
<tr>
<td>Improve machinery</td>
<td>89</td>
<td>2.7</td>
</tr>
<tr>
<td>Increase fitness of workers</td>
<td>74</td>
<td>2.2</td>
</tr>
<tr>
<td>No night shift</td>
<td>64</td>
<td>1.9</td>
</tr>
<tr>
<td>Total</td>
<td>826</td>
<td>24.8</td>
</tr>
</tbody>
</table>

The following sections show each of the major areas of classification with detail regarding the most commonly reported topics specific to each area and the type of change suggested by respondents. In addition, examples of comments made by survey respondents representing the underlying issues relating to each topic are provided.

WORK TASKS

The most frequently reported major category after classification was work tasks (see Table A.1). Within this category, the most prevalent responses related to changing the jobs/duties that older workers are involved in, changing the physical demands of the tasks, and job rotation. Table A.3 provides a summary of the major topics in this category.

TABLE A.3 Summary of major topics in Work Tasks category

<table>
<thead>
<tr>
<th>Topic</th>
<th>Number</th>
<th>Response Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change jobs/duties of older workers</td>
<td>307</td>
<td>46.9</td>
</tr>
<tr>
<td>Change physical demands of tasks of older workers</td>
<td>169</td>
<td>25.8</td>
</tr>
<tr>
<td>Job rotation</td>
<td>98</td>
<td>15</td>
</tr>
<tr>
<td>Other</td>
<td>80</td>
<td>12.2</td>
</tr>
<tr>
<td>Total</td>
<td>574</td>
<td>100</td>
</tr>
</tbody>
</table>

Of the 307 responses suggesting changing the jobs and duties, 19% recommended better matching of jobs to older workers, a further 16%
suggested providing opportunities for older miners to move into training roles and 15% suggested placing them into supervisors’ roles. In addition, 13.7% suggested that placing older miners into out-bye positions would be the most appropriate way to ensure older miners continued working safely and productively.

Of the 169 comments relating to the physical demands of tasks, 87% of responses indicated that physical demands should be decreased for older workers. The balance of comments in this sub-topic suggested that the demands of a task should be matched with the ability of the worker (9.5%).

With regard to job rotation, 95% of the 98 responses in this topic indicated that the amount of rotation should increase.

**Summary of work tasks**

- **Change jobs/duties**

  Almost half the responses in this category indicated that the jobs and duties of older workers should be modified to better suit their changing abilities and skills, including age-appropriate jobs structure to suit their level of skills and expertise.

  Additionally, several comments suggested placing older workers into training or supervisor roles, thus enabling younger and less experienced workers to learn from their peers and utilise the expertise of older miners.

  Several suggested that out-bye positions or surface roles may best suit older workers, with some recommending that as miners get older they should gradually move closer to the surface.

- **Change physical demands of tasks**

  The most common suggestion regarding the physical demands of work was to decrease the physical exertion required by older workers. This data relates well to the results obtained from the open-ended question in Survey 2 (see Appendix 2), in which older miners with one or more current injuries rated their experience of the physical demands of the task, and the frequency in which they undertook these tasks, higher than older miners without any current injury. One of the tasks older injured miners rated significantly more physically demanding than older injury-free miners was manual handling.

  Several of the responses relating to a reduction in physical demands included suggestions that manual handling activities should be reduced or replaced with the increasing the use of technology. Other comments suggested that the heavy tasks should be allocated to the younger workers, while older miners should have the opportunity to work in less physically demanding jobs. Respondents indicated that by reducing the physical
demands placed on older workers, a reduction in the rate of injury among these workers may also be achieved.

In addition to decreasing the physical demands allocated to older workers, respondents suggested altering or adjusting the physical demands of work with ageing, or modifying the job requirements to better suit the capabilities of the worker. Respondents recommended matching jobs and duties according to the fitness, physical condition or other physical attributes of the older miner.

- **Job rotation**

With regard to increasing job rotation, respondents suggested that older miners should be allocated less repetitive tasks and have increased variety in their work day to keep the mind stimulated. This would enable older miners to be involved in multiple tasks on a shift, therefore avoiding boredom or loss of concentration on more repetitive tasks.

**WORK ORGANISATION**

A total of 630 comments indicated that work organisation was of primary concern for the safety and productivity of older workers (Table A.1). This was the second most common category (with health) after work tasks. The most reported topic within work organisation was related to shifts, followed by rosters, and crew levels (see Table A.4).

**TABLE A.4 Summary of major topics in Work Organisation category**

<table>
<thead>
<tr>
<th>Topic</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shifts</td>
<td>383</td>
<td>60.8</td>
</tr>
<tr>
<td>Rosters</td>
<td>95</td>
<td>15.1</td>
</tr>
<tr>
<td>Crew Levels</td>
<td>52</td>
<td>8</td>
</tr>
<tr>
<td>Other</td>
<td>100</td>
<td>16.1</td>
</tr>
<tr>
<td>Total</td>
<td>630</td>
<td>100</td>
</tr>
</tbody>
</table>

The most commonly reported overall response to the open-ended survey question was that the number of hours worked per shift should be reduced (see Table A.2). *Decreasing shift length* represented 69% of responses coded within the shifts topic. A further 16.7% of these respondents suggested *taking older workers off night shift* duties to improve their safety and increase their productivity.

In relation to the 95 responses coded under work rosters, the majority (53%) suggested that *improvement in rosters* was required. The other common, but less frequent, response (19%) was to *make rosters more flexible*.

Of the 52 comments relating to crew levels, 86.3% suggested that *crew levels needed to be increased* to improve the safety and productivity of the older workers.
Summary of work organisation issues

- **Shifts**

More respondents suggested that decreasing the length of shifts would improve the safety and productivity of older miners than any other single action per se. A large proportion of comments about hours of work suggested the discontinuation of 12-hour shifts and replacing them with 8-hour shifts.

Some survey respondents specified that older miners should not be required to perform night shift duties and should be placed on day shift only. Many of these indicated that older workers should not be on rotating rosters, but instead should be allocated permanent day work only.

- **Rosters**

In regard to rosters, most responses suggested that older workers should be allowed to work 5-day rather than 7-day rosters to improve their safety and productivity. Others suggested that the rosters should be more flexible to allow for extra time for families, rest and recreation.

- **Crew levels**

Comments about crew levels focused on increasing Manning numbers, thus having more people to share the workload.

**HEALTH**

Health issues were equal second with work organisation issues in terms of the most frequent response topics, representing almost one-fifth (n = 630) of all responses to this open-ended question. Of these, the majority (81%) suggested that older miners could improve their health through increased fitness, better nutrition, more rest and sleep, or improved self-monitoring through avenues such as weight control. Workers felt these factors would help older miners to continue working safely and productively, as their own health would be improved and thus, their physical capacity would be increased, leading to more tolerance of the physical tasks involved with mine work and hence, lower injury risk.

Within this primary classification, topics of the highest frequency included the general health and well-being of mine workers, fitness and diet and nutrition (see Table A.5).
### TABLE A.5 Summary of major topics in Health category

<table>
<thead>
<tr>
<th>Topic</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>General health &amp; well-being</td>
<td>238</td>
<td>37.7</td>
</tr>
<tr>
<td>Fitness</td>
<td>226</td>
<td>35.8</td>
</tr>
<tr>
<td>Diet &amp; nutrition</td>
<td>47</td>
<td>7.5</td>
</tr>
<tr>
<td>Other</td>
<td>119</td>
<td>19</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>630</td>
<td>100</td>
</tr>
</tbody>
</table>

Within the 238 *general health* comments, the most commonly reported suggestions were to provide support for the maintenance of general health (18.5%), to improve the overall general health of workers (16.8%) and to screen for health problems within this population (16%).

Of the 226 responses indicating that *fitness* was the most important area within health, 43.5% suggested that an improvement in fitness was required. Within the smaller group of comments relating to *diet and nutrition*, the majority (61%) indicated that these elements needed to be improved.

Almost one-fifth of responses (119 comments) were unable to be coded at a third level.

### Summary of health issues

- **General health**

  A focus on the provision of company support for the maintenance and improvement of general health and well-being emerged from the responses, with many comments suggesting the work environment should provide appropriate medical support, more frequent health clinics and more company-sponsored wellness programs. Respondents also suggested that mining companies should provide more support for the management of ailments and the rehabilitation of workplace injuries.

  Some commentators indicated that individual miners should improve their own general health through a reduction in the intake of substances including drugs and alcohol, the cessation of smoking, and by making general lifestyle changes, including improved dietary intake and increased fitness.

  With regard to screening for health problems, respondents indicated that more frequent medical examinations were required, as well as regular health assessments.
Fitness

Improvement in fitness levels emerged as a common factor that may help older miners to continue to work safely and productively into the future. Respondents suggested that increasing the levels of personal fitness and adopting a general commitment to fitness and physical activity both at work and away from work would be required.

Diet & nutrition

The smaller number of respondents who suggested that diet and nutrition played a major role in ensuring the future safety and productivity of older miners focused on improving the intake of foods, eating healthily and maintaining a well-balanced diet.

OTHER CLASSIFICATIONS

As shown in Table A.1, other relevant areas within the primary classification included training, management, safety and ergonomics.

Training

One-fifth (21.7%) of the 294 responses related to training in specific tasks, including manual-handling protocols, new procedures and other high-risk work procedures. Other suggestions included motivational sessions, fatigue management, hazard awareness and risk assessment.

Management

Of the 262 responses classified in management, 24% suggested greater appreciation of older workers, while 22.5% indicated that improvement in communication was required. For example, some suggested older workers need to be respected for the time they have spent in the industry and therefore need more recognition and encouragement from their managers. Others indicated that management should listen more to older workers, who have a wealth of experience to share, and that they should be given more opportunity for input into operations.

Safety

Safety of the individual was the most common topic within the safety category, with 29.2% of all 240 safety comments relating to the individual. An additional 17.5% of responses indicated that safety training was also an important topic.

With regard to individual safety, respondents suggested that older miners need to be aware and alert all the time, should stop and think before doing a job and should not rush. Comments relating to safety training indicated that workers needed more safety discussions and should be provided with additional opportunities to learn new safety rules and regulations.
**Ergonomics**

Of the 224 responses coded within the category of *ergonomics*, 126 indicated that *machinery* was the most important area, with 70% of those comments suggesting *improvement in machinery* was required to ensure the ongoing safety of older workers and improved productivity. This was the fifth most common response overall (see Table A.2). Better ergonomic design and improved maintenance were common recommendations.

**SUMMARY**

Based on the survey results, respondents suggested a number of areas they perceived as most relevant to improving the ability of older workers to continue working safely and productively into the future. The single most common response was to decrease the number of hours worked per shift, with a large majority recommending a reduction in shift length from 12 hours to 8 hours. Other responses relating to the organisation of shifts suggested that older miners should not work night shift, but instead should be placed on a permanent day shift roster.

Other frequent responses suggested a focus on modification of work tasks, with a reduction in physical demands the most common suggestion in this regard. Aligned with this is the suggestion that older miners should be placed in training or supervisory roles, thus limiting their physical involvement in the workplace, while allowing them to share their experience and knowledge with others.

Alternatively, respondents suggested that older miners should be involved in increased job rotation to provide respite from heavy-duty tasks and to eliminate or reduce workplace boredom.

From a company perspective, another common response was related to improvements in the availability and condition of machinery used in the mining industry. Suggestions related to improving the design of machines to limit or reduce the manual handling involved with a number of work tasks.

At the individual worker level, respondents suggested older workers could improve their personal fitness to enhance their work performance and safety. As improved fitness relates to better physical condition, this would enable them to continue working in roles requiring heavy-duty tasks.
APPENDIX 2

RESPONSES TO OPEN-ENDED QUESTION (Sample 2)

List in order the three most important factors you believe contribute to avoiding injury in the workplace

In response to this open-ended question, respondents in the second survey were required to list the three most important factors they believed would contribute to avoiding injury in the workplace. The major categories that emerged after classification are outlined in Table 1 with safety, health and training being the prominent topics.

**TABLE A.6** Response categories as a percentage of total responses

<table>
<thead>
<tr>
<th>Category</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>143</td>
<td>32.5</td>
</tr>
<tr>
<td>Health</td>
<td>84</td>
<td>19.1</td>
</tr>
<tr>
<td>Training</td>
<td>67</td>
<td>15.2</td>
</tr>
<tr>
<td>Ergonomics</td>
<td>34</td>
<td>7.7</td>
</tr>
<tr>
<td>Individual issues</td>
<td>28</td>
<td>6.4</td>
</tr>
<tr>
<td>Management</td>
<td>22</td>
<td>5</td>
</tr>
<tr>
<td>Work organisation</td>
<td>20</td>
<td>4.5</td>
</tr>
<tr>
<td>Work tasks</td>
<td>16</td>
<td>3.6</td>
</tr>
<tr>
<td>Social issues</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td>Irrelevant</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>440</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Further classification identified the most frequent topics workers thought would assist in workplace injury prevention (Table A.7).

**TABLE A.7** Most frequent topics mentioned by respondents

<table>
<thead>
<tr>
<th>Response</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve training in specific work tasks</td>
<td>50</td>
<td>11.4</td>
</tr>
<tr>
<td>Improve safety awareness</td>
<td>47</td>
<td>10.7</td>
</tr>
<tr>
<td>Increase health and fitness</td>
<td>35</td>
<td>8</td>
</tr>
<tr>
<td>Workers being careful whilst on duty</td>
<td>26</td>
<td>5.9</td>
</tr>
<tr>
<td>Increase rest and sleep</td>
<td>21</td>
<td>4.8</td>
</tr>
<tr>
<td>Other</td>
<td>261</td>
<td>59.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>179</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

The remaining 261 survey comments not included in Table 2 had a frequency of less than 4.5% overall and therefore have not been detailed here.
Each of the major categories will now be reviewed and specific views from survey respondents will be discussed to provide further insight into the views of the mine workers themselves.

SAFETY

Safety issues represented the most frequently occurring category of responses (n = 143), accounting for almost one-third (32.5%) of all comments. The most common topics to emerge from the data within the safety category were to maximise individual safety awareness, to ensure individuals are being careful in their work environment, and to ensure individuals are complying with safety procedures (see Table A.8).

**TABLE A.8 Most frequent topics in the Safety category**

<table>
<thead>
<tr>
<th>Response</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve safety awareness</td>
<td>47</td>
<td>32.9</td>
</tr>
<tr>
<td>Workers being careful whilst on duty</td>
<td>26</td>
<td>18.2</td>
</tr>
<tr>
<td>Compliance with safety procedures</td>
<td>17</td>
<td>11.9</td>
</tr>
<tr>
<td>Other</td>
<td>53</td>
<td>37</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>143</td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Improved safety awareness was the second most common response type overall. Respondents suggested that individuals need to be aware of their workplace conditions by being observant, maintaining alertness and staying focused on the job at hand. Several comments related to being particularly aware of workplace hazards and assessing each work area before commencement of a specified task.

Closely related to this area are the comments regarding caution in the work environment. These responses related predominantly to avoiding rushing jobs and taking time to complete tasks safely. Some indicated that workers should think about the job before starting it and look after themselves by putting their own safety first.

A smaller number of respondents made reference to individuals complying with safety procedures by following all safety rules and regulations to ensure adherence to safe work practices.
HEALTH

Health was the second most frequent topic raised by respondents (n = 84) to this question. Within this category, the most frequent topics to emerge were increasing the health and fitness of workers, increasing the amount of sleep, improving nutrition and diet and improving general health (see Table A.9).

**TABLE A.9 Most frequent topics in the Health category**

<table>
<thead>
<tr>
<th>Response</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase health and fitness</td>
<td>35</td>
<td>41.7</td>
</tr>
<tr>
<td>Increase sleep</td>
<td>21</td>
<td>25</td>
</tr>
<tr>
<td>Improve nutrition and health</td>
<td>11</td>
<td>13.1</td>
</tr>
<tr>
<td>Improve general health</td>
<td>10</td>
<td>11.9</td>
</tr>
<tr>
<td>Other</td>
<td>7</td>
<td>8.3</td>
</tr>
<tr>
<td>Total</td>
<td>84</td>
<td>100</td>
</tr>
</tbody>
</table>

Increasing the health and fitness of workers was the third most frequent response (see Table A.7). Comments relating to this topic suggested that workers need to keep themselves fit and healthy, maintain an active involvement in physical fitness regimens and participate in regular aerobic sport to improve fitness levels.

Respondents also suggested more sleep would help workers to be better prepared for their shift, to avoid workplace injury, and should be a priority for all workers. Less frequent responses in the health category related to nutrition and general health, with comments suggesting healthy food and being in good health were important.

TRAINING

Of the 440 responses, 67 comments related to training. Of those, 75% reported that improvement in training for specific tasks was required. This was the single most commonly reported response to this survey question (see Table A.7). Specific comments suggested training in tasks was important in order for workers to have the necessary knowledge and competence to do their job.

The additional 25% of comments relating to training were less specific and could not be coded at a second level.

OTHER CATEGORIES

Ergonomics was addressed in 34 responses, with the most common suggestions being to improve the working environment and to improve machinery. Respondents suggested the work environment should be kept clean and tidy, and that suitable machinery should be provided and maintained to enhance safety on the job.
Individual issues raised in 28 responses (6.4% of all comments) related mostly to ensuring employee attitudes remained positive, while 22 comments (5%) focused on the provision by management of adequate supervision to maintain safety standards.

Other classifications with a response rate of less than 5% were not included in this analysis.

SUMMARY

The three most prevalent responses from this analysis relating to factors that would contribute to workplace injury prevention were improvement in training for specific tasks, improved safety awareness, and increased health and fitness. Safety was of concern to a large segment of respondents, with the majority of these comments relating to the individual worker being careful, taking precautions and being aware of their immediate working environment.

These actions have been suggested by the workers themselves and therefore any change in industry protocols or recommendations should consider the value of these suggestions for injury prevention among mine workers.
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</tr>
<tr>
<td>3.23</td>
<td>Frequency of reported current injuries by job category and mine type</td>
<td>96</td>
</tr>
<tr>
<td>3.24</td>
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<td>98</td>
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