Underground coal mining injury: A look at how age and experience relate to days lost from work following an injury

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A B S T R A C T

Coal has been mined in the United States since colonial times and coal mining has always been a dangerous occupation. Despite the dangers involved in coal mining, coal is essential to the functioning of our society. Coal provides energy for products, businesses, and homes. Not only is coal mining a dangerous occupation, but, like many other industries, coal mining has also been referred to as a "graying occupation" as many coal miners are reaching retirement age. Younger workers possess certain advantages as older workers may have age-associated decrements in cognitive function, health, and recuperative ability. Although there are documented decreases in health and safety associated with age, there are also benefits at the workplace associated with increasing age. Increasing age brings about more experience and familiarity with the work environment. This study used the Mine Safety and Health Administration's (MSHA) database on accidents, injury, and illness from the years 2003 through 2007 to examine how age, experience at the current mine, total years experience as a coal miner, and experience in the current job affects injury severity. The results of the data indicated that there was a relationship between age and days lost as well as total mining experience and days lost following an injury. Furthermore, the data indicated an increased risk of overexertion injuries as age increases. These are important findings for the coal mining industry as many miners are more experienced and older.

1. Background

Coal mining has been dangerous occupation since mining of coal began during colonial times (Reardon, 1993). The deadliest year in US coal mining history was 1907 when 3242 people died (Mine Safety Health Administration, 2007). That year was highlighted by an explosion in Monongah, WV which killed 358 people (Mine Safety Health Administration, 2007). Due to high fatality rates during the early 1900s at coal mines, in 1910 the US Bureau of Mines was founded. The US Bureau of Mines was created to conduct research and develop technologies to reduce safety and health risks to miners. Since its inception, the US Bureau of Mines has achieved a significant reduction in mining injuries and fatalities and improvements in health. This reduction in the number of deaths is partly due to "pioneering research on hazard identification and control," (National Research Council, 2002, p. 4) which has been conducted by the US Bureau of Mines and later became part of the National Institute for Occupational Safety and Health (NIOSH). More stringent legislation later followed in 1969 and 1977 which led to a number of safety improvements. Between 2003 and 2007, the number of deaths per year of coal miners ranged from 23 to 47 deaths; which is a substantial reduction from 3242 deaths in 1907.

Despite increased safety measures and decreased death toll, coal mining has received national attention as a dangerous industry, partly from recent highly publicized disasters. Even though research and new practices continue to reduce the dangers of the industry, its reputation is somewhat warranted when coal mining is compared to other industries. The 1992 census found that workers in mining have a higher risk of workplace fatalities relative to their share of employment (Toscano and Windau, 1993). A look at fatal occupational injuries from 1980 to 1997 found that mining had the highest death rates (Centers for Disease Control and Prevention (CDC), 2001). In more recent years, coal miners continue to experience a high injury rate. In 2006, there were 3021 non-fatal lost-time injuries among coal miners occurring at a rate of 3.3 injuries per 100 full time equivalent employees (US Department of Health and Human Services (DHHS), 2008). The Bureau of Labor Statistics (BLS) has also found that employees in coal mining are more likely to be killed or sustain an injury or illness than workers in private industry. These injuries are also likely to be more severe (BLS, 2007a). In fact, the rate of non-fatal injuries and illnesses in coal mining in 2005 was 11% higher than for total private industry. The injury rate is even higher in underground bituminous coal mining; the rate of non-fatal injuries and illnesses was 63% higher

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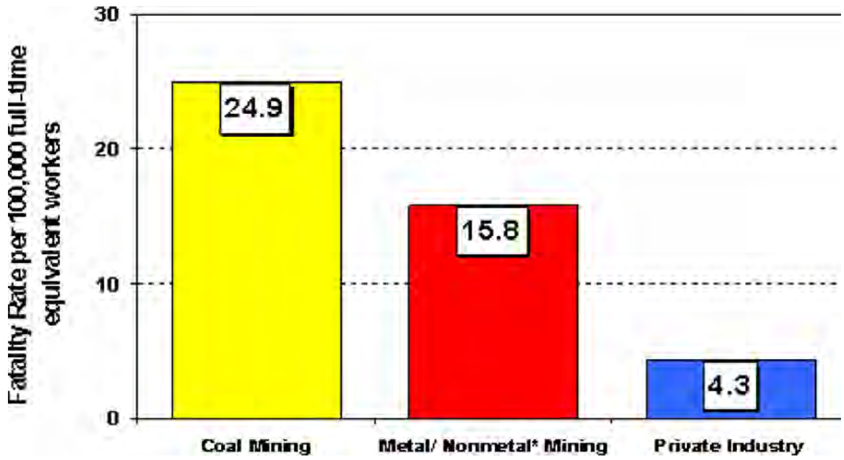

Fig. 1. Fatality rate for coal and metal/nonmetal mining and private industry, 2007. (Data comes from the Bureau of Labor Statistics (BLS), the Census of Fatal Occupational Injuries (CFOI) and the Current Population Survey (CPS). Metal/nonmetal mining includes metal, nonmetal, stone, and sand and gravel mining. Data reported for the metal/nonmetal industry are not available separately from the CFOI program).

than that of all private industry (BLS, 2007a). Fig. 1 illustrates the higher rate of fatality for coal mining compared to metal/nonmetal mining and private industry in 2007.

Despite the dangers involved in coal mining, coal is essential to the functioning of our society. Coal provides energy for products, businesses, and homes. More than 51% of electricity in the United States is generated through burning coal (United Mine Workers of America (UMWA), n.d.). For this reason, coal production continually rises and will likely continue to do so as the US is estimated to have over 250 years of coal reserves available for mining (UMWA, n.d.). Because coal is essential to society and there appears to be no immediate limit to its mining, it is important to understand injuries in coal mining. Furthermore since coal mining injuries tend to be more severe (BLS, 2007a) it is important to understand who is suffering the most severe injuries in coal mining in hopes of reducing their occurrence and severity.

Not only is coal mining a dangerous occupation, but, like many other industries (Pransky et al., 2005) coal mining has also been referred to as a "graying occupation" as many coal miners are reaching retirement age. According to the National Mining Association (NMA), in 2006 the mean age of a coal miner was 50 and the median was 47 (NMA, 2007). The age of a coal miner can be compared with the entire civilian labor force where the median age has been steadily increasing and was 40.8 in 2006 (BLS, 2007b).

This growth in older workers across all industries, not just coal, can be attributed to the aging Baby Boomer Generation (Schwerha and Mallett, 2005). Among those aged 55–64, 60% are in the workforce and 14% of those over the age of 65 are in the workforce (Rogers and Wiatrowski, 2005). Furthermore, certain policies and budget cuts indicate that older workers will comprise a larger portion of the workforce in the future and will need to continue working past retirement age (Besl and Kale, 1996). It is estimated that by the year 2025, 30% of the North American workforce will be over the age of 55 (Ilmarinen, 2001). Therefore, there is a trend in the US of an increasingly older workforce; however, this trend is even more pronounced for coal mining.

An aging workforce has certain implications for health and safety as workers aged 65 and above have the highest age-specific occupational death rate (Centers for Disease Control and Prevention (CDC), 2001). An older workforce also has important implications for coal mining. First, this means that there will be an influx of young and inexperienced coal miners. Secondly, there are numerous miners who are older and possibly more prone to severe injury. These two factors could have important effects on the injuries in coal mining.

Due to the current demographics of the mining industry, the first hypothesis is advanced. It is predicted the older a worker is, the more severe an injury that he/she will suffer. Specifically, it is posited that age will be positively related to days lost from work. The evidence for how experience impacts miners' safety is less lucid. Therefore, a research question is posed which asks how experience at the current mine, total years experience as a coal miner, and experience in the current job is related to days lost from work.

2. Literature review

2.1. Age

Younger workers in many cases possess certain capabilities over older workers including increased strength, speed, and precision (Ilmarinen, 2001). They do, however, have less experience and training which can hinder both their performance and safety. Often, injuries and fatalities are not only a matter of youth but are also due to inexperience. Workers often experience higher injury rates during their 1 year on a new job or when they start working for a new employer (Siskind, 1982). Looking at the impact that younger workers have on injury rates, Mitchell (1988) found that employees under the age of 25 are more likely to become injured on the job compared to older workers. Mitchell (1988) attributes this to a higher prevalence of temporary injuries due to inexperience. Although Mitchell (1988) does not define temporary injuries these are usually injuries which are not permanent, such as paralysis, and will heal such as a sprained ankle.

Breslin and Smith (2005) examined age-related differences in work injuries with a representative sample of Canadians aged 15 and older. It was found that the younger groups of workers, were more likely to sustain a work injury than were adults over 35 (Breslin and Smith, 2005). Although this provides evidence that younger workers are more likely to become injured on the job, it clusters all older workers above the age of 35 in one group. This clustering might miss some of the injury trends for older workers as there are large differences in the capabilities of a 35 year old and a 55 year old. Furthermore, this study only looked at the frequency of injury and did not include severity statistics.

Increased age also becomes a concern as workers may have age-associated decrements in cognitive function, health, and recuperative ability (Pransky et al., 2005). Older workers also have decreased physical abilities such as changes in their maximal oxygen consumption and musculoskeletal capacity after the age of 45–50 (Ilmarinen, 2001). Kowalski-Trakolfer et al. (2005) point out that the aerobic capacity of a 65 year old is about 70% of a 25 year old. For these reasons, there currently exist numerous studies on the effects of age and injuries in the workplace. Meyer (2005) found that a worker aged 55 or older in farming was more than 10 times more likely to be fatally injured than workers as a whole.

Another study that looked at how age and injury are related only examined older workers and clustered younger workers with middle-aged workers. In this study, Pransky et al. (2005) found that among workers who had lost time due to injury in New Hampshire, older workers reported more comorbidities than did those who were under the age of 55. Duration of lost time, however, was not different for those above 55 and those below 55 (Pransky et al., 2005).

Another way to look at how age relates to injury is to look at age as a continuous variable and not break it into clusters. Feuerstain et al. (1999) did examine age as a continuous variable and found that among US Army soldiers every increase in age by 1 year brought along an increased risk for a low back disability. This study did not, however, examine lost work time or severity of injury by age.

2.2. Experience

Although there are documented decrements in health and safety associated with age, there are also benefits at the workplace associated with increasing age. Increasing age brings about more experience and familiarity with the work environment. Some studies have found that older workers are not more prone to injury because they are able to use experience and resources more efficiently to avoid injury (Laflamme and Menckel, 1995). As workers age they do gain improved cognitive function in some areas including the ability to process complex problems in insecure situations and control of the use of language (Ilmarinen, 2001). These are important skills to have during a mine emergency. Furthermore, older workers may be able to overcome shortcomings in speed, strength, and precision with increased motivation, experience, and wisdom which they have acquired during their work tenure (Ilmarinen, 2001). Laflamme and Menckel (1995) reviewed 22 studies and found evidence that older workers do possess a compensatory ability to reduce difficulties in meeting job demands. Breslin and Smith (2006) studied Ontario workers and also found that injury claim rates declined as time on the job increased.

2.3. Severity of injury

Although frequency of injury may not increase as workers age, severity may. Severity of injury is often considered the number of days lost from work after an injury. In a later study, Laflamme et al. (1996) specifically examined male iron-ore miners in Sweden. It was found that as age increased there was no escalation in frequency of accident. There was, however, a rise in the severity of accidents as age increased. In this study, severity of injury was operationalized as the number of days lost from work and it was found that workers aged 55–65 tended to lose a greater number of days from work due to an injury than younger workers (Laflamme et al., 1996). This study is one of the few studies to examine how age affects injury in a mining setting. However, it examines iron-ore workers in Sweden. Underground coal mining is known to be the most dangerous form of mining in the US. The US also has different safety regulations from Sweden. Therefore, this study cannot be generalized to US coal mining but it does provide a good foundation for future research in the US.

Because there is mixed evidence about exactly how age relates to injury, some studies have examined both rate of injury and severity of injury. Mitchell (1988) found that younger workers had a higher rate of injury but employees aged 65 and above suffer more serious job related injuries. Wiatrowski (2005) examined the BLS data for the year of 2003 and also found that those 65 and older had a lower incidence of injury but had the highest median days away from work due to an occupational injury or illness. Furthermore, approximately 40% of injuries that involved days lost among those 65 and older involved 31 days or more off from the job (Wiatrowski, 2005).

There are, however, very few studies that examine the effect of age on mining safety, specifically coal mining. Coal mining must be studied separately from other occupations and types of mining as it has a higher average age of worker than the overall work force and it is more dangerous. The work environment of coal mining also provides unique challenges to safety and health. It is, therefore, important to examine how aging specifically affects safety in coal mining.

3. Methods

Data came from the Mine Safety and Health Administration's (MSHA) database on accidents, injury, and illness, which includes injury data reported from all underground coal mines. Data from the years 2003 through 2007 were combined to form one data set with a sample size of 10,345. Data were only included from coal operator employees and not contractors. The data set only reports data on characteristics of injured miners. It does not include demographic data about all workers or frequency of injury to various categories of workers. It is important to note that mining differs vastly by method of mining, type and mineral. Therefore, this study chose to examine only underground coal mining so that the results are more interpretable. Furthermore, coal mining was chosen because it has the highest rate of non-fatal injuries among all types of mining (McDermott, 1997). Within coal mining, underground coal mining had substantially more injuries than surface mining (Bureau of Labor Statistics, 2007a). For these reasons, the present study will only examine underground bituminous coal mining as it is the most dangerous form of mining. Therefore, it is important to understand these injuries in order to reduce them.

In order to test the hypothesis and research question, the data were restricted to only include injuries where one or more days of work were lost due to injury. Age was generated from the birth date where the median was 43.00 ($SD = 11.22$) and the range was 17–79 years. Age was normally distributed; yet, slightly platykurtic.

Experience was measured with three different variables. Total mining experience was measured in years with a median of 13.90 years ($SD = 14.85$) and a range of 0.02–46.00 years. Experience at this mine had a median of 2.00 years ($SD = 7.65$) with values ranging from 0.02 to 38.06 years. Experience in this job was also measured in years and had a median of 3.00 years ($SD = 7.76$). The range was 0.02–44.00 years. All three experience variables exhibited slight positive skews.

The severity of injury was operationalized as the number of days lost from work after an injury and was measured using MSHA's actual days lost variable. This variable does not include statutory days lost but instead measures the actual number of days lost due to injury. Only values greater than or equal to 1 day lost were included in the analysis. The median for this variable was 32.00 days ($SD = 77.23$) with a range from 1 to 376. Days lost was slightly positively skewed.

In order to assess the hypothesis, a multiple regression analysis was conducted with age and the three experience variables as independent variables and days lost as the dependent variable. The analysis appeared to meet all of the assumptions of multiple regression. The plot of residuals versus predicted values implied that there were independent errors and that the assumption of homoscedasticity was not violated. There also did not appear to be any outliers that should be removed from the analysis. There also was no evidence of multicollinearity as there were no tolerance values less than 0.10. Although the distribution of the data was not perfectly normal, other studies have shown that in large data sets normally distributed data are not necessary for regression and *t*-tests (Lumley et al., 2002). This data set included 9627 cases list-wise so it is large enough to withstand slight violations to the assumption of normality.

The results of the multiple regression analysis revealed that there was a significant relationship between the independent variables and the actual days lost due to injury, $F(4, 9623) = 30.24$, $p < .001$. R for the model was 0.11 and adjusted R^2 was 0.01. The relationship between age and days lost was statistically significant, $\beta = 0.78$, $t(9623) = 4.69$, $p < .001$. The relationship between total mining experience and days lost was also statistically significant $\beta = 0.37$, $t(9623) = 1.97$, $p < .001$.

Because age and total mining experience were the only significant relationships, the other two experience variables were removed from the model and the regression analysis was conducted again. When days lost from work was regressed onto age and mining experience total, the relationship was significant, $F(2, 9761) = 59.08$, $p < .001$. R for the model was 0.11 and adjusted R^2 was 0.01. The relationship between age and days lost remained statistically significant, $\beta = .07$, $t(9761) = 4.52$, $p < .001$. The relationship between total mining experience and age also remained statistically significant, $\beta = 0.04$, $t(9761) = 2.46$, $p = .014$.

Therefore, these data show that age and total mining experience have an influence on severity of injury such that as age and total mining experience increases the number of days away from work following an injury also increases. This relationship, although statistically significant, is slight and greatly influenced by the large sample size. Furthermore, experience at this mine and experience in this job do not have an effect on severity of injury.

Because the data allowed for further assessment of the role that age plays in injury, an analysis to gain a more nuanced understanding of this relationship was sought. One type of injury that may be more likely to occur as age increases is the overexertion injury. Kumar (1994) points out that overexertion injury can occur due to direct trauma, a single overexertion, or frequent or sustained load to the body. As miners age, they have likely not only sustained load to the body but their physical strength also decreases (Kumar, 1994). Therefore, the body has weakened capacity and is more likely to suffer from overexertion. Due to this, the relationship between age and overexertion injury was assessed.

Increasing age was hypothesized to result in an increased risk of overexertion injuries compared to all other types of injury. In order to assess this relationship, a logistic regression analysis was conducted. The accident type variable was recoded so that all types of overexertion injuries were given a value of 1 and all other types of injuries were recoded to a value of 0. Age was initially used as a continuous-scaled variable; however, it did not meet the assumption of linearity in the logit. Three design variables were then created for age, less than 30 years, 31–50 years, and more than 50 years. The reference group was the less than 30 years. The results of the logistic model showed an increased risk of overexertion injuries as age increases. For the 31–50 age group, the estimated odds of an overexertion injury, compared to the reference group were 1.554, $p < .0001$, while for the over 50 group, the odds were equal to 1.937, $p < .000$.

4. Discussion

McDermott (1997) reports that injuries in mining are more severe than other industries as miners often miss more days of work after an injury. It is, therefore, important to study the severity of mining injuries and what is associated with these injuries in an attempt to reduce them. Once more is known about variables associated with mining injury severity, steps can be taken to reduce the severity of injury. For example, specific safety programs could be developed for older workers to avoid injury.

This study takes a step in attempting to reduce the severity of mining injuries by trying to better understand variables that may be affecting injury. One of the biggest shifts in the mining industry as of late is an aging workforce and the addition of younger, inexperienced workers to the industry. Inexperience in the workforce may affect mining injury severity as mining requires a great deal of safety training. And the present study found that total mining experience was related to an increase in the number of days lost from work.

As more inexperienced miners enter the workforce an emphasis on training will be necessary to reduce injury among the new workers. Improved training for coal miners has been linked to better health and safety outcomes (Braithwaite, 1985). Instead of simply training workers on how to operate equipment or perform a task, training should also include how to avoid an injury. Castillo and Rodriguez (1997) conducted a national survey of people who were injured while working and found that 66% of workers had not received training on how to avoid injury while doing their line of work. Shannon et al. (1997) found that a greater amount of training was related to lower injury rates. In a review of 80 studies, Cohen and Colligan (1998) found that training not only increases worker knowledge of job hazards but also affects safer work practices. Training could also focus on how to avoid certain types of injury such as overexertion injuries.

The literature often suggests a link between job experience and injury. However, the present study only found a slight relationship between total mining experience and severity of injury. As total mining experience increases, miners miss more days of work after suffering an injury. There was also, a relationship between age and severity of injury. As age increases, miners miss more days of work after an accident. Although it is often assumed that an older miner is likely to miss more days of work than a younger miner after an injury, there have not been any studies to show if this relationship does exist. Furthermore, before the present study there was no evidence as to how strong this relationship might be. Therefore, the present study confirms that there is a statistically significant and positive relationship between age and days lost from work after an injury. There was also a relationship between age and overexertion injuries such that as age increases the likelihood of an overexertion injury increases. It should be noted, however, that the relationship between age and severity of injury is not as strong as some might have expected. Furthermore, this relationship was also more likely significant because of the large sample size.

Also there are other factors that could account for differences in severity of injury. As coal miners become more experienced, the type of jobs that they perform may change. For example, a more experienced worker is likely to be in a supervisory role. This study is not experimental so it cannot be shown that age or experience causes increased severity of injury but can only highlight that there is a relationship. Future studies can, therefore, look to see what other variables may have an impact on severity of injury.

This study also points to future directions for research in this area. The present study examined the severity of injury using days lost. However, future studies can expand on these results by collecting data and examining how the frequency of injury relates to age and experience. When looking at frequency of injury, as opposed to severity of injury, there may be a stronger relationship between experience and injury.

This study also points to the importance of collecting more safety and demographic data on coal mining in the future. There are certain inherent limitations in the data set used in this paper as there is no measure of frequency of injury for coal miners. Currently MSHA only collects data on age and experience when an injury occurs so it is not possible to measure frequency of injury as there is no data on the age of all miners in the workforce. Although BLS also collects data on coal mining, it does not report how age relates to frequency of injury for underground coal mining. The National Institute for Occupational Safety and Health (NIOSH) is currently working to solve this problem by conducting a national survey of mining that may allow researchers to examine how age relates to frequency of injury. This is important as little research has been conducted on mining demographics and injury since 1986. It is important that these data be collected more often as changes in technology, technique, and demographics could affect rate of injury. These data could play a crucial role in reducing fatalities and injuries by pinpointing specific characteristics that lead to an increased risk of injury.

Despite the limitations with these data, this paper is a first step for the mining industry. Very little has been done to analyze data related to age and experience and other variables that may be related to safety and health in mining. This study found a relationship between increasing age and increasing time away from work after an injury. This is an important finding when considering that the average age of a coal miner is 50 (National Mining Association, 2007). Safety trainers should consider the safety of older workers and consider training them about behaviors that would be unique for older workers to help avoid injuries and, therefore, avoid time away from work. Possible directions for training include focusing on preventing musculoskeletal injuries or preventing falls. New interventions are being developed to help improve balance training and reduce falls among older adults (Maki et al., 2008). Interventions such as these can be adopted for miners in the workplace. An even more comprehensive training program could be used to train the entire workforce about the effects of aging on safety and health (i.e. Porter et al., 2008). Such training may help miners understand early warning signs of cumulative trauma disorders and what they can do to prevent lost-time injuries.

It is also important to note that the finding that there is not a statistically significant relationship between experience in this job and experience at this mine and severity of injury is as valuable as finding a statistically significant result. This study shows that experience may not play as crucial a role in severity of injury as has been previously thought. Since this study did not find a statistically significant relationship between these types of experience and severity of injury. Future research could look at the relationship between injury and variables such as length of shift, amount of sleep, number of breaks, and drug use.

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