An analysis of injury claims from low-seam coal mines

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ABSTRACT

Introduction: The restricted workspace present in low-seam coal mines forces workers to adopt awkward working postures (kneeling and stooping), which place high physical demands on the knee and lower back. *Method:* This article provides an analysis of injury claims for eight mining companies operating low-seam coal mines during calendar years 1996-2008. All cost data were normalized using data on the cost of medical care (MPI) as provided by the U.S. Bureau of Labor Statistics. *Results:* Results of the analysis indicate that the knee was the body part that led in terms of claim cost ($4.2 million), followed by injuries to the lower back ($2.7 million). While the average cost per injury for these body parts was $13,100 and $14,400, respectively (close to the average cost of an injury overall), the high frequency of these injuries resulted in their pre-eminence in terms of cost. Analysis of data from individual mining companies suggest that knee and lower back injuries were a consistent problem across companies, as these injuries were each among the top five most costly part of body for seven out of eight companies studied. *Application/Impact:* Results of this investigation suggest that efforts to reduce the frequency of knee and low back injuries in low-seam mines have the potential to create substantial cost savings.

1. Introduction

Low-seam coal mines (mines having a coal seam of 1.2 m or less) compel workers to adopt postures that impose significant physical loading on the musculoskeletal system (Gallagher, 2005). The limited vertical space in these mines prohibits upright standing, and workers must spend the entirety of their work shift in kneeling or stooping postures. Not surprisingly, frequent kneeling has been associated with an increased risk of knee disorders, including knee-joint inflammation, bursitis, and osteoarthritis (Sharrard, 1963; Myllymaki, Tikkakoski, Typpo, Kivimaki, & Suramo, 1993; Manninen, Heliovarra, Riihimaki, & Suomalainen, 2002). The stooping posture has similarly been associated with an increased risk of low back disorders. Such postures have been associated with up to an 8-fold increase in low back disorders among autoworkers (Punnett, Fine, Keyserling, Herrin, & Chaffin, 1991), and also have been associated with degenerative changes in the lumbar spines of underground mine workers (Lawrence, 1955; Brinckmann, Forbin, Biggemann, Tillotson, & Burton, 1998). Given these relationships, it is important to develop an awareness of the societal burden associated with these injuries.

One approach to better understanding the relative importance of different types of occupational injuries and illnesses with respect to incidence and severity is to analyze administrative databases. An example is workers compensation (WC) records, which have been analyzed for several research purposes. Examples include analysis by antecedent event to prioritize a research agenda (Murphy, Sorock, Courtney, Webster, & Leamon, 1996), analysis within claims attributed to certain occupational exposures to better understand research and practice needs for that exposure (Dempsey & Hashemi, 1999), and analysis of a specific body part and nature of injury combination to understand jurisdictional variations in cost (Webster & Snook, 1994).

One important source of accident/injury data in mining is the Mine Safety and Health Administration (MSHA) database. Stobbe, Bobick, and Plummer (1986) used these data to estimate the burden of MSDs in underground coal and metal/nonmetal mines. In both industry segments, the back accounted for over 50% of reported strains/sprains, and was usually attributed to materials handling activities. For coal, knees had the highest mean days lost per strain/sprain with a mean of 30.8 days lost in 1984 compared to 21.1 days lost for the back. More recently, Moore, Bauer, and Steiner (2008) used the MSHA database to examine trends in the incidence of musculoskeletal disorders (MSDs) by comparing 1983-1984 data with 2003-2004 data. During that time period, low-back MSDs decreased from 41% to 31% of the reported injuries/illnesses while knee MSDs increased from 9% to 17%.

One drawback of the MSHA database is that it does not contain information regarding the financial costs associated with specific accidents or injuries. As a current research initiative at the National Institute for Occupational Safety and Health (NIOSH) Pittsburgh Research Laboratory is targeted toward reducing knee disorders in underground coal mines, researchers were interested in obtaining WC costs of knee injuries in low-seam coal mines, and comparing these costs to injuries involving other parts of the body. Appreciation of the financial

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costs associated with these injuries may help motivate intervention strategies to reduce injury risk in low-seam coal mines.

2. Methods

Injury claims from eight coal mining companies operating low-seam mines were obtained from a cooperating insurer. These claims were comprehensive in that they represented the totality of claims submitted to the insurance company by the various mining companies over a particular time frame. Researchers were unaware of the company names or locations as the data were provided in a format where mine operators were identified by different letters of the alphabet. Data from these mining companies were provided for differing time frames, ranging from a low of 4.75 years to a high of 12.0 years, dependent on the length of time for which the companies were insured with the cooperating insurance company. All data provided for this analysis were collected during the years ranging from 1996-2008 inclusive. The average length of time for which data were provided by a given company was 7.8 years $\pm$ 2.4 SD. Unfortunately, the staggered starting and ending times of coverage for the various companies made it impossible to assess overall injury trends. Thus, researchers focused on analyzing the data with respect to the cost of injuries to various parts of the body.

Table 1
Summary of costs by body part over all low-seam coal operating companies (May 2008 dollars).

Body Part	Frequency	Cost	% Total Cost	Average Cost/ Injury
Knee	318	$4,172,600	17.39	$13,100
Lower back	187	$2,688,600	11.20	$14,400
Multiple body parts	52	$1,947,200	8.11	$37,400
Whole Body	10	$1,706,100	7.11	$170,600
Shoulders	84	$1,324,200	5.52	$15,800
Finger(s)	175	$1,209,000	5.04	$6,900
Soft Tissue	33	$1,143,200	4.76	$34,600
Disc (Lumbar)	2	$848,200	3.53	$424,100
Multiple body systems	7	$801,300	3.34	$114,500
Multiple trunk	5	$746,900	3.11	$149,400
Chest	27	$730,300	3.04	$27,000
Lung	22	$652,200	2.72	$29,600
Upper arm	22	$564,200	2.35	$25,600
Pelvis	11	$527,600	2.20	$48,000
Foot	53	$501,100	2.09	$9,500
Lower leg	23	$483,600	2.02	$21,000
Thigh / upper leg	17	$430,200	1.79	$25,300
Hand	106	$426,300	1.78	$4,000
Hip	6	$362,500	1.51	$60,400
Eye(s)	91	$317,700	1.32	$3,500
Ankle	26	$290,200	1.21	$11,200
Elbow	36	$251,300	1.05	$7,000
Abdomen (including groin)	45	$243,900	1.02	$5,400
Multiple upper extremity	8	$213,400	0.89	$26,700
Toe(s)	7	$190,600	0.79	$27,200
Vertebrae	1	$179,700	0.75	$179,700
Wrist	45	$163,500	0.68	$3,600
Great toe	1	$110,700	0.46	$110,700
Ear(s)	20	$99,400	0.41	$5,000
Thumb	29	$96,500	0.40	$3,300
Other facial soft tissue	49	$92,400	0.39	$1,900
Buttocks	2	$92,000	0.38	$46,000
Lower arm	34	$79,000	0.33	$2,300
Upper back	41	$76,000	0.32	$1,900
Wrist(s) and Hand(s)	8	$40,900	0.17	$5,100
Facial bones	3	$32,500	0.14	$10,800
Nose	14	$31,200	0.13	$2,200
Internal Organs	8	$29,400	0.12	$3,700
Multiple lower extremities	6	$25,500	0.11	$4,300
Multiple neck injury	3	$22,500	0.09	$7,500
Teeth	12	$11,600	0.05	$1,000
Disc (Cervical)	1	$11,600	0.05	$11,600
Skull	7	$10,900	0.05	$1,600
Mouth	9	$5,600	0.02	$600
Sacrum and coccyx	3	$5,400	0.02	$1,800
Multiple head injury	6	$5,000	0.02	$800
Artificial appliance	2	$1,600	0.01	$800
Brain	1	$1,200	0.00	$1,200
No physical injury	1	$500	0.00	$500
Total	1678	$23,997,000	100.00	$14,300

Table 2
Injury frequency, total costs, and average cost per injury for individual mining companies.

Mining Company	Time Frame	Injury Frequency	Total Cost	Average Cost/ injury
C	9/1/1996 - 9/1/2005	168	$ 2,225,800	$ 132,500
B	5/1/2001 - 5/1/2008	136	$ 3,351,600	$ 24,600
I	6/1/1996 – 7/1/2005	277	$ 5,259,700	$ 19,000
D	8/1/1996 - 8/1/2003	60	$ 1,014,600	$ 16,900
J	5/1/1996 – 5/1/2008	347	$ 5,326,600	$ 15,400
H	8/1/2003 – 5/1/2008	534	$ 5,669,800	$ 10,600
F	11/1/1999 - 5/1/2008	126	$ 974,900	$ 7,700
G	2/15/2000 - 2/1/2005	31	$ 174,100	$ 5,600

The time frame represents the period during which claim data was available for each individual company.

Costs for medical claims for each mining company were indexed for inflation by using data on the cost of medical care (MPI) as provided by the U.S. Bureau of Labor Statistics (www.bls.gov). Since the time frames for company data often spanned two calendar years, the inflation adjustment was performed using the monthly MPI data. For example, if cost data were provided for a company for the time period May 1, 2004 through May 1, 2005 the monthly MPI data were obtained from the BLS and the average of the MPI for the 12 months from May 2004 through April 2005 was calculated. This value was used to adjust the cost of the claims for inflation.

3. Results

For ease of presentation, all cost data in this article have been rounded to the nearest hundred dollars. Table 1 provides a summary of costs by the part of body injured for all of the low-seam coal mines studied in order of descending total cost. As can be seen in this table, several of the leading body parts affected by injury are associated with the musculoskeletal system. In particular, injuries to the knee and lower back are the two leading body parts in terms of injury cost and together are responsible for 28.6% of the total costs incurred by the eight mining companies studied. These two body parts also lead in terms of injury frequency in these data. In fact, the average cost of an individual injury to the knee or back ($13-14K) ranks very close to the mean cost for all injuries; however, the high frequency with which these injuries occur leads to their pre-eminence in terms of cost. Shoulders ranked as the fifth most costly part of body injured (and had the fifth highest injury frequency), and accounted for an additional 5.5% of the total injury cost.

In discussing the costs associated with musculoskeletal injuries, it may also be noted that injuries to lumbar (low back) spinal discs ranked eighth in terms of total cost with a frequency of only two injuries. The cost of these two injuries ($848,200) was driven by a single case that was over $750,000 by itself, and made lumbar disc injuries by far the leader in terms of average cost per injury. If one considers injuries to the lumbar discs as a type of lower back injury, the combined cost of these injuries increases to over $3.5 million.

Besides the injuries to body parts discussed above, the top 10 most costly include several categories that involve injury to multiple body parts or systems. Four such categories appear in the top 10 most costly injuries, including: multiple body parts (3rd), whole body (4th), multiple body systems (9th), and multiple trunk (10th). These injuries tend to have a relatively low frequency of injury (i.e., a frequency of 10 or less for three of these four categories) but a relatively high average cost. Unfortunately, it is difficult to interpret the nature of these types of injuries since it is unclear specifically what body parts or systems

Table 3
Top five leading part of body injured in terms of percentage of total cost (May 2008 dollars) for individual mining companies (B-J).

	B	C	D	F	G	H	I	J
1st	Whole Body (50.3%)	Chest (25.1%)	Soft Tissue (45.2%)	Finger (59.7%)	Lower back (34.1%)	Lower back (23.0%)	Multiple body parts (24.6%)	Knee (44.7%)
2nd	Multiple body systems (10.2%)	Lung (19.1%)	Knee (40.9%)	Great toe (11.0%)	Ear (21.3%)	Multiple trunk (11.2%)	Disc (Lumbar) (15.8%)	Pelvis (9.4%)
3rd	Knee (9.5%)	Knee (18.3%)	Lower back (3.1%)	Knee (7.3%)	Shoulder (17.1%)	Knee (10.3%)	Shoulder (13.1%)	Upper arm (6.3%)
4th	Lower back (8.0%)	Lower back (12.2%)	Shoulder (3.0%)	Ankle (7.2%)	Abdomen (including groin) (7.6%)	Multiple body systems (8.6%)	Lower back (8.9%)	Hip (6.1%)
5th	Hand (7.8%)	Shoulder (3.5%)	Wrist (1.4%)	Abdomen (including groin) (3.8%)	Knee (6.5%)	Multiple body parts (6.4%)	Lower leg (8.7%)	Lower back (6.1%)

Numbers in parentheses represent the percentage of total costs accounted for by the specified part of body.

were injured. However, it must be considered likely that a different combination of parts or systems were injured for each instance thus classified, making generalizations regarding these categories even more difficult.

Rounding out the top 10 most costly body parts are fingers and soft tissue injuries. Fingers had the third highest injury frequency (175 cases), but had the lowest average injury cost of body parts appearing in the top 10 ($6,900). Soft tissue injuries ranked 7th overall with just 33 instances and an above average cost of $34,600 per injury. Overall the top 10 body parts injured accounted for 69% of the total injury cost, with 40 other categories accounting for the balance.

Table 2 provides information regarding the injury frequencies and cost for the individual companies operating low seam mines and provides information regarding the time frame for which injury data were available for each mine. Unfortunately, the authors did not have specific denominator data for these mines, so the injury frequency and cost data may simply reflect differences in the size of the workforce at these different mining companies. There is wide variability of the mining companies in terms of the average injury cost, which very well may be influenced by one or a few claims in each case. Raw data were not available to calculate median costs, which tend to exhibit less variability. The lowest average injury cost of these companies is that of company G ($5,600 per injury), which is more than four times lower than that of mine B, which had the highest average cost of $24,600.

Table 3 provides information on a mine by mine basis on the top five leading body parts injured in terms of cost incurred over the time for which claim data were available from each company. As can be seen from this table, each mine exhibits a unique combination of body parts representing its top five most costly. However, as noted in Table 4, certain body parts appear more frequently in the top five most costly injuries across the eight companies studied. Specifically, the knee and the lower back each appear in the top five most costly for seven out of the eight companies operating in low-seam conditions. The shoulder is the next most frequent body part, and appears in four of the eight top five most costly injury lists. Multiple body parts, multiple body systems, and abdomen (including groin) appear in the top five most costly two times each, and the balance (comprising 16 body part categories) appear only one time each.

Table 4
Frequency with which specific body parts appeared in the top 5 most expensive injuries across the eight companies.

Number of times in top 5 across eight companies	Body Parts
7	Knee, Lower Back
4	Shoulders
2	Multiple Body Parts, Multiple body systems, Abdomen (including groin)
1	Whole Body, Hand, Chest, Lung, Soft Tissue, Wrist, Fingers, Great Toe, Ankle, Ear, Multiple Trunk, Disc, Lower leg, Pelvis, Upper Arm, Hip

4. Discussion

The restricted workspace present in low-seam coal mines forces workers to adopt awkward working postures (kneeling and stooping), which place high physical demands on specific joints of the body. The present analysis makes clear that both the knee and the lower back have very high frequencies of injury in this environment, and the data illustrate that knee injuries and lower back injuries are a consistent problem across all of the mining companies studied. As a result of the high frequency of injury to these two body parts, the costs associated with knee and lower back injuries lead in terms of the injury burden experienced in low-seam coal mines.

The findings of this analysis of injury claims are congruent with other studies that have examined the effects of working in restricted postures. With respect to the effects on the lower extremity, Sharrard (1963) reported on the results of examinations on 579 coal miners in a study examining the etiology of "beat knee." Forty percent of the miners reportedly were symptomatic or had previously experienced symptoms, characterized as acute or simple chronic bursitis. Incidence rates were found to be higher in seam heights lower than four feet and in workers required to kneel for prolonged periods at the mine face. The incidence of "beat knee" was found to be higher in younger mine-workers; however, this finding was thought to be due to a "healthy worker" effect. Specifically, it was thought that older workers with "beat knee" might have already left the mining profession.

Studies examining other occupations where frequent kneeling is necessary have also found higher rates of knee problems than comparison occupational groups (Tanaka, Smith, Halperin, & Jensen, 1982; Myllymaki et al., 1993; Coggon et al., 2000; Jensen, Mikkelsen, Loft, & Eenberg, 2000; Sandmark, Hogstedt, & Vingard, 2000; Nahit, Macfarlane, Pritchard, Cherry, & Silman, 2001; Manninen et al., 2002). Tanaka et al. (1982) found that occupational morbidity ratios for workers compensation claims involving knee-joint inflammation for carpet layers was over 13 times greater than that of carpenters, sheet metal workers, and tinsmiths. Knee inflammation among tile setters and floor layers were over six times greater than the same comparison groups. Workers in these occupations have been shown more likely to exhibit fluid accumulation in the superficial infrapatellar bursa, subcutaneous thickening of this bursa, and increased thickness in the prepatellar region (Myllymaki et al., 1993). The much higher incidence associated with carpet layers is probably also related to their use of a knee-kicker, a device used to stretch carpet during its installation. Knee impact forces during the use of this device have been shown to be as high as four times body weight (Bhattacharya, Mueller, & Putz-Anderson, 1985).

In terms of lower back injuries, an early study by Lawrence (1955) examined British coal miners to identify factors related to degenerative disk changes, and found that injury, duration of heavy lifting, duration of stooping, and exposure to wet mine conditions were the factors most associated with spinal changes. Another study investigating spinal changes in miners was reported by MacDonald, Porter, Hibbert, and Hart (1984). These investigators used ultrasound to measure the spinal canal diameter of 204 coal miners and found that those with the greatest morbidity had significantly narrower spinal canals. The study by Lawrence (1955) suggests that the seam height of the mine has a marked influence on the incidence of low back disorders. The finding of increased low back claims in conditions where stooping is common is similar to other evidence relating non-neutral trunk postures to low back disorders. For example, a case-control study by Punnett et al. (1991) examined the relationship between non-neutral trunk postures and risk of low back disorders. After adjusting for covariates such as age, gender, length of employment, and medical history, time spent in non-neutral trunk postures (mild or severe flexion and bending) was strongly associated with back disorders (OR 8.0, 95% CI 1.4-44). Although it was difficult in their study to find subjects that were not exposed to non-neutral postures, the strong increase in risk observed with both intensity and duration of exposure were notable.

There is also evidence that the kneeling posture not only impacts the frequency of knee injuries, but may affect low back pain rates, as well. A study of 1773 randomly selected construction workers also examined the effects of awkward working postures on the prevalence rates of low back pain (Holmstrom, Lindell, & Moritz, 1992). This study found that prevalence rate ratios for low back pain were increased for both stooping ($p<0.01$) and kneeling ($p<0.05$) when the duration of work in these postures were reported to be at least one hour per day. Furthermore, a dose-response relationship was observed whereby longer durations of stooping and kneeling were associated with increased prevalence rate ratios for severe low back pain.

Several limitations associated with our analysis must be noted. Because individual claims costs were not available, means rather than medians were reported. Medians are commonly used in analysis of workers compensation claims to minimize the influence of outliers, and the data provided to the authors did not allow for their use. Additionally, claims cost overall was adjusted using medical inflation because the component medical, indemnity, and other costs were not available for individual claims. Since medical costs are often a reasonably high percentage of workers compensation claims for musculoskeletal disorders, the authors feel that this limitation would have only a modest influence on the conclusions drawn.

5. Conclusions

Results of the current analysis of injury claims from low-seam coal mines allow several conclusions to be drawn. One conclusion is that musculoskeletal disorders as a whole represent a significant portion of the total injury burden experienced by low-seam coal mines. Injuries to three joints of the body (knee, lower back, and shoulder) represent approximately one-third of the total costs of injuries experienced by these mines. This finding is fairly consistent across the mining companies studied. Furthermore, it is apparent that the restricted vertical space present in these mines, which obligates mine workers to adopt a kneeling posture for the majority of the workday, exacts a significant toll on the knee joint, making it the most frequent injury and most costly body part in terms of injury claims. Although knee pads are often used in these environments, these data suggest that kneepads are not a sufficient means to control these injuries and that additional measures need to be taken. Additional research is necessary to further investigate the nature and severity of knee claims so that potential preventive measures can be postulated and more effective safety and health approaches developed.

Acknowledgements

The authors gratefully acknowledge the assistance of Rockwood Casualty Insurance Company, who supplied the claims information reported in this paper, and who provided valuable assistance and guidance in this effort. The authors also gratefully acknowledge the contributions of Diana Schwerha, PhD, Lisa Steiner, MS, and William J. Wiehagen, MS in the development of this manuscript. Disclaimers: Mention of any company or product does not constitute endorsement by NIOSH. The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

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