Fall from equipment injuries in U.S. mining: Identification of specific research areas for future investigation

Susan M. Moore *, William L. Porter, Patrick G. Dempsey

National Institute for Occupational Safety and Health, USA
Pittsburgh Research Laboratory, USA

A B S T R A C T

Introduction: The objective of this study was to evaluate the circumstances leading to fall from equipment injuries in the mining industry. *Method:* The 2006 and 2007 Mine Safety and Health Administration annual injury databases were utilized for this study whereby the injury narrative, nature of injury, body part injured, mine type, age at injury, and days lost were evaluated for each injury. *Results:* The majority of injuries occurred at surface mining facilities (~60%) with fractures and sprains/strains being the most common injuries occurring to the major joints of the body. Nearly 50% of injuries occurred during ingress/egress, predominately during egress, and approximately 25% of injuries occurred during maintenance tasks. The majority of injuries occurred in relation to large trucks, wheel loaders, dozers, and conveyors/belts. The severity of injury was independent of age and the median days lost was seven days; however, there was a large range in severity. *Impact on industry:* From the data obtained in this study, several different research areas have been identified for future work, which include balance and stability control when descending ladders and equipment design for maintenance tasks.

1. Introduction

Slips, trips, and falls are one of the leading causes of occupational morbidity and mortality across a variety of administrative data systems designed to capture such data (Murphy, Sorock, Courtney, Webster, & Leamon, 1996). In 2007, the Bureau of Labor Statistics (BLS, 2008) report indicated that over 24% of nonfatal occupational injuries and illnesses involving days away from work could be attributed to 'fall to lower level,' 'fall on same level,' and 'slip, trip, loss of balance without fall' event or exposure classifications. For mining, the National Institute for Occupational Safety and Health (NIOSH, 2008) reported that 25% of nonfatal lost-time injuries from 2002-2006 were attributed to slip or fall of person.

A subset of slip or fall of person injuries is due to falls from equipment, and accounted for 2.7%, or nearly 400, of all mining related injuries in 2007 (Mine Safety & Health Administration, 2007). Factors associated with these falls are largely unknown and, therefore, cannot be completely accounted for in design of equipment, development of work practices, or in training programs for mine workers. Further understanding of the etiology and circumstances of these injuries will allow engineering controls, administrative controls, and perhaps personal protective equipment to be developed to reduce the incident and severity of injuries from falls from equipment. Moreover, this information could be used to generate research questions specifically addressing fall from equipment type injuries in the mining industry, and also in other sectors such as construction.

Some falls from equipment occur as mine workers enter and exit equipment via the ladder or stair systems. Fairly extensive research has already been conducted regarding ladder and stair climbing (Bjornstig & Johnsson, 1992; Bloswick, 1999; Bloswick & Chaffin, 1990; Bloswick & Crookston, 1992; Chang, Chang, & Matz, 2005; Chang, Chang, Matz, & Son, 2004; Dewar, 1977; Fathallah & Cotnam, 1998, 2000; Giguere & Marchand, 2005; Hakkinen, Pesonen, & Rajamaki, 1988; Hammer & Schmalz, 1992; Hoozemans et al., 2005; Kowalk, Duncan, & Vaughan, 1996; McIntyre, 1983; Partridge, Virk, & Antosia, 1998; Patenaude, Marchand, Samperi, & Belanger, 2001; Shepherd, Kahler, & Cross, 2006; Yang & Ashton-Miller, 2005). Much of this research focused on impact forces during various descent techniques, friction requirements, or the effect of physical changes to ladders (e.g., ladder slant, rung separation). Additionally, a portion of this research is most applicable to situations where the individuals would be entering and exiting equipment on a routine basis (e.g., parcel delivery).

Another subset of fall research focuses on individuals utilizing a ladder for the purpose of completing an occupational task (e.g., painting a house). In fact, Partridge and coworkers (Partridge et al.,

Funding: National Institute for Occupational Safety and Health.
* Corresponding author. 626 Cochrans Mill Road, PO Box 18070, Pittsburgh, PA 15236, USA. Tel.: +1 412 386 6613; fax: +1 412 386 6764.
E-mail addresses: SMMoore@cdc.gov (S.M. Moore), WLPorter@cdc.gov (W.L. Porter), Pdempsey@cdc.gov (P.G. Dempsey).

1998) conducted a retrospective study of ladder fall injuries and found that the majority of injuries resulted from excessive reaching or incorrect ladder placement with 50% of the falls being occupationally related. Although ladders on equipment are largely fixed in place, these findings may be relevant if ladders on equipment are used for maintenance or other tasks besides ingress/egress, even if the intended purpose of the ladder/stair is equipment access. It is currently unknown what proportion of injuries in mining occur during the ingress/egress process, and whether these access systems may contribute to fall from equipment injuries resulting from use of the system for purposes other than equipment ingress/egress.

In addition to falls associated with the ingress/egress systems of equipment, other falls may result from mine workers performing procedures outside the cab that are routine or non-routine parts of their job. Understanding what these tasks are and how miners go about performing them will be very helpful to develop preventive measures to minimize risk of fall while performing them.

Other factors such as age may also be associated with falls from equipment. As individuals age, they have instability of gait and falls are common (Kane, Ouslander, & Abrass, 1994). Thus, there may be an association between age and injury frequency or severity (e.g., days lost).

Understanding contributing factors to falls from equipment injuries in mining will help direct future research areas and develop recommendations for prevention. Therefore, the objective of this study was to determine (for a two-year sample of fall from equipment injuries) the mine type where injury occurred, nature of injury, body part injured, the activities being performed just prior to the fall from equipment, the type of equipment involved, and any contributing factors such as loss of balance or environmental conditions (e.g., icy). A secondary objective was to determine if age was a factor in the frequency and/or severity of fall from equipment injuries.

2. Methods

The Mine Safety and Health Administration (MSHA) provides an annual administrative database that details all reportable injuries, illnesses, and fatalities sustained in mining. Due to the low number of fall from equipment injuries suffered each year (<400), two years of data were evaluated for the purpose of this study. The two most recent years at the onset of the study were selected for evaluation (2006 and 2007). Injuries classified as falls from equipment were extracted from the full year databases for further analysis.

The type of mine where the injuries occurred, nature of injury (e.g., contusion, dislocation, fracture), body part injured, age of miner, and days lost were contained in the data. For all but the age of the miner and days lost, both years were combined for these analyses since there were a wide variety of categories for each.

Other data required interpretation of narratives and manual coding, and both years were evaluated separately for the remaining analyses. For this coding, the factors below were determined jointly by the authors. Two reviewers (SMM and WLP), one per database (2006 and 2007, respectively), then read the narratives provided for each injury and categorized the following factors:

1.) Injury scenario (ingress/egress; maintenance; standard procedures; other; or unknown);
    1a.) if the injury occurred while getting on or off equipment, during which phase of the ingress/egress process did it occur (ingress, egress, or unknown);
2.) Whether the injured party had an object in their hand (yes, no, or unknown);
3.) Method of injury (e.g., fell backwards, slipped and fell);
4.) Type of equipment involved (e.g., wheel loader, dozer);
5.) Stated contributing factors (e.g., lost balance, dizziness); and
6.) Environmental factors (e.g., wet, icy, muddy).

Once the first reviewer completed their analysis, the reviewers switched databases and evaluated factors 1, 1a, and 2. Following these two independent reviews, all injury narratives with discordant ratings between reviewers were determined. For each discrepancy, the two reviewers and an independent third party (PGD) discussed the narratives and arrived at a uniform decision regarding its classification.

For both the 2006 and 2007 databases, frequencies for the scenario during which the injury occurred, ingress versus egress, whether or not an object was clearly in the hand, and the type of equipment were then calculated. The number of injuries occurring under poor environmental conditions was also noted and the method of injury was also investigated for any unexpected information. The averages and medians of mine worker age and the total lost days were calculated.

3. Results

The total number of injuries reported as occurring due to a “fall from equipment” was 394 and 393 for 2006 and 2007, respectively. For 2006, the age of the mine worker at the time of injury was omitted for six entries while four were omitted from the 2007 database. When evaluating the percentage of falls by mine type, it was observed that the majority (63%) of the injuries occurred at surface mines where open pit or strip mining was being conducted. Mill or preparation plants accounted for 18% of the injuries, and underground mines accounted for 12%.

Only four types of equipment could be identified that each accounted for at least 5% of the injuries: dozers, large trucks, wheel loaders, and conveyors/belts (Fig. 1). The equipment in the “other” category was extremely diverse and, therefore, could not be grouped into larger categories for the sake of analysis. Drills, mucking machines, and crushers are examples of equipment that fell into the “other” category.

The activity the mine worker was conducting at the time of injury proved to be quite telling, with injuries during ingress/egress and maintenance tasks being most common (Fig. 2). For both years, approximately 75% of the ingress/egress injuries occurred during egress.

The majority of the narratives were too vague to determine whether or not the individual was holding an object at the time of injury. In fact, less than 5% of the narratives provided enough information to make this determination, all of which indicated that an object was in fact in the hand at the time of injury.

Based on the information provided in the narratives, only 23 injuries (5.8%) reported in 2006 had contributing environmental factors such as wet or icy conditions, with 2007 having 37 injuries (9.4%). Noteworthy contributing factors mentioned in narratives included dizziness, loss of balance, equipment malfunction (e.g., handrail breaks), cleaning of windows, and losing control of one's equipment (e.g., runaway haul truck). The method of injury was rarely reported to be a trip. Rather, slips and falls accounted for the majority of the injuries. It should also be noted that a handful of injuries occurred as the operator jumped out of/off a vehicle. In fact 32 injuries occurred in this manner in 2006 and 25 occurred in 2007. In some cases this was because of fire or it was a runaway vehicle. In 2006, eight incidents occurred when an operator jumped from a wheel loader while four incidents occurred when the operator jumped from a truck. Four incidents also occurred when the operator jumped from a train or railcar. In 2007, four incidents occurred with the operator jumping from a wheel loader and seven incidents occurred with an operator jumping from a truck. Many other types of equipment had two or fewer incidents. This equipment included, but is not limited to, excavators, dozers, conveyors/belts, scoop, and continuous miners.

Only six types of injuries accounted for 5% of the injuries or more: sprains/strains (36%); fractures/chips (28%); contusions/bruises (12%); unclassified/not determined (9%); multiple injuries (6%); and cuts/lacerations/punctures (5%). Thus, more than 50% of the injuries sustained from the falls were fractures/chips or sprains/strains. Just

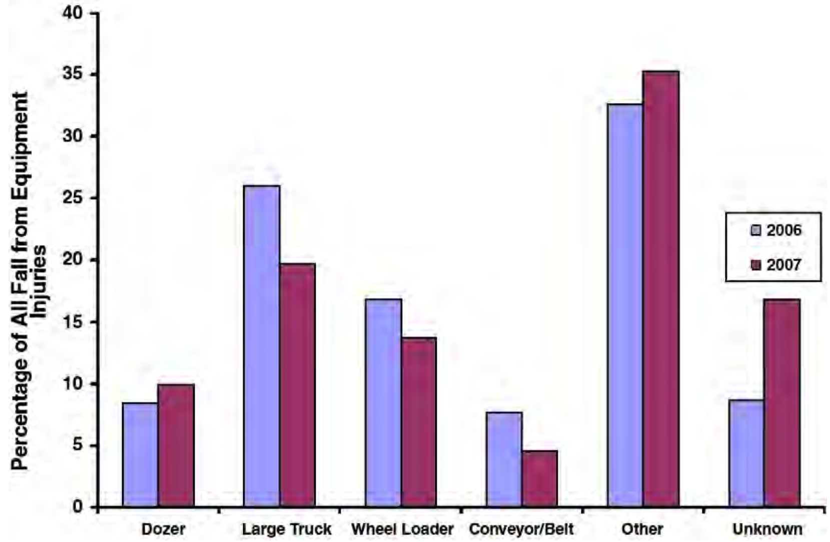

Fig. 1. Percentage of "fall from equipment" injuries in 2006 and 2007 that occurred on various types of equipment.

over 10% were contusions/bruises. With respect to body part, 8%-15% of the injuries were to each the back, shoulders, knees, and ankles. The total number of injuries to the back, shoulders, knee, and ankle were 115, 62, 92, and 89, respectively.

In 2006, a return to work date was not provided for three injury claims and for 2007 a total of eight injury claims did not have a return to work date. One reason for this might be that statutory days lost were charged for severe injuries (e.g., amputation). In these cases, the MSHA database lists the days lost at zero. Therefore, these claims were removed from the database for the following analysis of days lost. Additionally, when return to work data are not available at close-out of the database each year, the one day after the close-out date is automatically issued as the return to work date. This was the case for two injuries in the 2007 database. The days lost up to the date when the database was closed out were included. While the days lost associated with these closed out cases may not be complete, excluding these injuries from the analysis may result in biased data since they may have been the more extreme cases with more days lost than demonstrated by the other data. Therefore, these two data entries were included in the following days lost analysis.

The median days lost was seven for 2006 and eight for 2007 and ranged from 0 to 362 for both databases. The 25th percentile days lost for both 2006 and 2007 was 0 days while the 75th percentile was 65 and 50 days, respectively. The 90th percentile days lost was 154 and 137, respectively. The median age at the time of injury in 2006 and 2007 was 43 and 44, respectively (Fig. 3). The ages ranged from 19 to 82 for 2006 and from 19 to 78 for 2007. Fig. 4 illustrates that severity of injury, or days lost, does not appear to be associated with age.

4. Discussion

In this study, the factors associated with fall from equipment injuries in mining were investigated for 2006 and 2007. The majority of fall from equipment injuries (>60%) occurred at surface mining facilities. The majority of injuries occurred in relation to large trucks, wheel loaders, dozers, and conveyors/belts. These pieces of equipment are often seen in surface mining operations, the most common mine type for the injuries investigated. It was found that nearly 50% of injuries occurred during the ingress/egress process, with most during egress. Additionally, injuries frequently occurred during maintenance

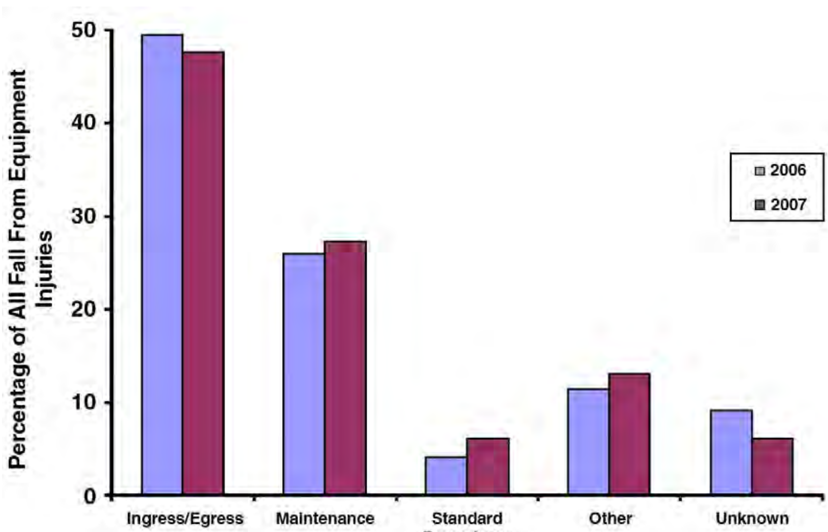

Fig. 2. Percentage of the "fall from equipment" injuries in 2006 and 2007 based upon the mine worker activity at the time of injury.

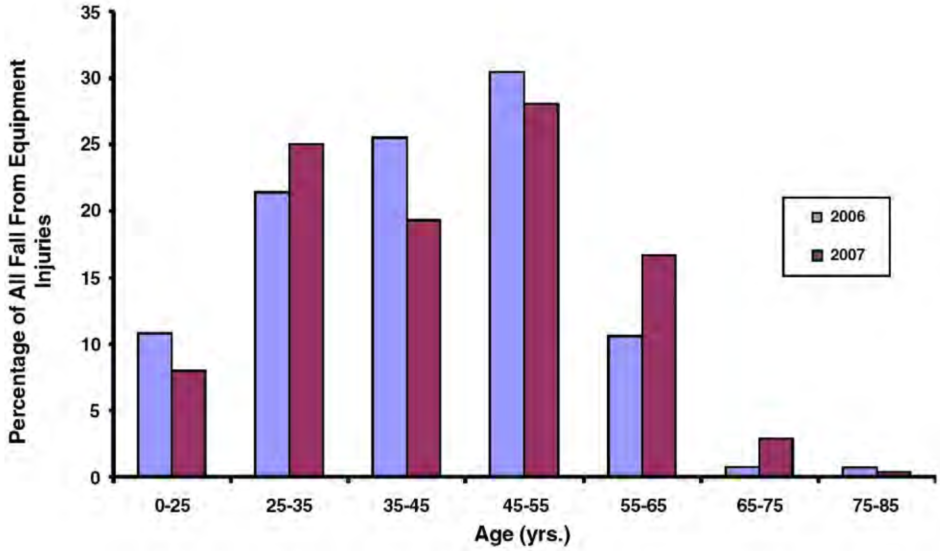

Fig. 3. Percentage of the "fall from equipment" injuries in 2006 and 2007 by age range.

tasks. Typically, the mode of injury was a fall, possibly proceeded by a slip. However, a number of injuries occurred as workers jumped from runaway equipment. Common injury types included fracture/chip and sprain/strain. The individual body parts most commonly injured were the back, shoulders, knees, and ankles. The severity of injury appeared to be independent of age and the median days lost was seven days; however, there was a large range in severity, which was nearly a full year in some cases.

In a 2001 study by NIOSH, Wiehagen, Mayton, Jaspal, and Turin (2001) reported a total of 875 serious injuries during ingress/egress of a dozer from 1988-1997. This averages out to be approximately 88 injuries per year. In the current study, ingress/egress injuries involving a dozer only accounted for approximately 9%, or around 35 injuries per year. Wiehagen et al. (2001) also reported 612 injuries that were related to maintenance and repair, averaging out to be about 61 injuries per year. In the current study, approximately 26% or 102 injuries per year occurred due to maintenance tasks. The differences between the two studies may be attributed to the methods used. In the 2001 study, the MSHA code titled "mine worker activity" was used to categorize injuries, while in the current study narratives from all fall from equipment type injuries were utilized. Other factors may have also played a role as manufacturers have made many improvements to dozers during the time between the two studies. Manufacturers have provided better walkways, handrails, and no-slip surfaces. Manufacturers have also improved access points for maintenance tasks that can now often be done at ground level. Some mines are even starting to put aftermarket stairs on their equipment. However, problems still exist with access around the cab (cleaning windows) and to maintenance areas (changing filters). Previous NIOSH efforts installed aftermarket ingress/egress aids on older equipment at several mines. Many of these mines viewed these aids as successful in reducing the risk of injury. A possible outcome may have been the industry's increased interest in ingress/egress systems. In fact, Catapillar is now including hydraulic ladders as an option. A second study by NIOSH (Randolph, 1997) reported that 48% of surface coal haulage truck accidents were a result of either ingress/

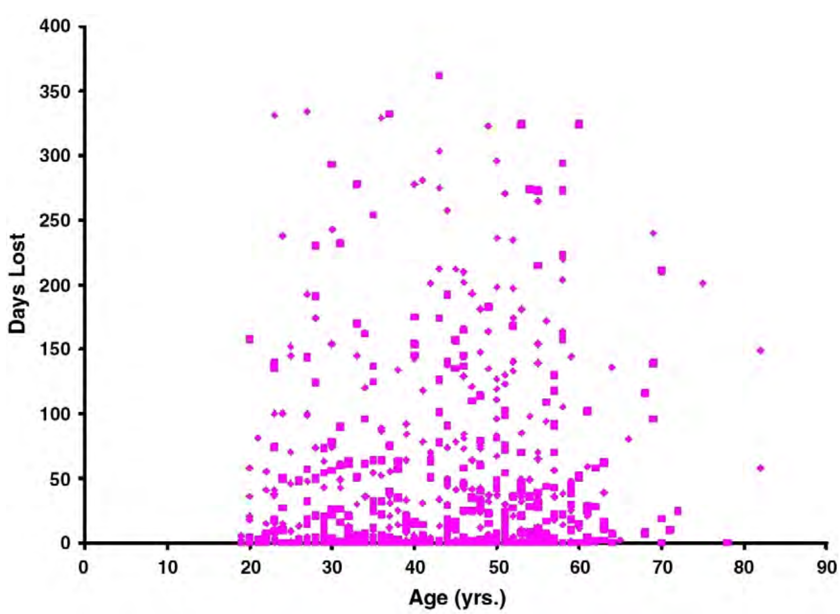

Fig. 4. Scatter plot showing the number of days lost as a function of age.

egress or maintenance. This further supports the findings of this study that these two categories are the primary modes of injury when a fall from equipment injury occurs.

The results of the current study clearly indicate that research focusing specifically on egress from large trucks, wheel loaders, and dozers may be beneficial to the field. Injuries may occur during egress since individuals are unable to see where their feet are landing when climbing down. The required coefficient of friction may also be higher during egress due to the differences between normal and non-normal forces during ingress versus egress. Additionally, the potential for slipping has been shown to greatly increase when exiting onto a slippery surface without using exit aids (Fathallah, Gronqvist, & Cotnam, 2000). As people age, they have instability of gait and falls are common (Kane et al., 1994), which may greatly affect their ability to descend ladders. This is an area in which current research regarding balance control (Cham & Redfern, 2001; Jacobson et al., 2001; Redfern & DiPasquale, 1997; Redfern, Jennings, Martin, & Furman, 2001; Redfern, Moore, & Yarsky, 1997; Redfern, Muller, Jennings, & Furman, 2002; Redfern, Yardley, & Bronstein, 2001; Schlesinger, Redfern, Dahl, & Jennings, 1998) could be expanded.

Another factor frequently associated with injury was maintenance. This may likely be due to the fact that equipment is often not designed well for maintenance tasks, causing mine workers to use various equipment features in ways they were not intended to be used. This could lead to individuals using undesirable methods to access the equipment, which may include make-shift materials or standing surfaces that are dangerous. Research to determine specifically what planned and unplanned equipment maintenance tasks are high risk and why are other possible research directions. This should be followed by an effort to communicate these findings with manufacturers and by making recommendations for design changes that could alleviate these problems.

Another area of interest observed by this study is the clear need to research the causes of runaway equipment. Nearly 10% of fall from equipment injuries occurred as mine workers attempted to jump from equipment. This averages out to be approximately two jumps from equipment per month. The primary equipment involved was wheel loaders and trucks. This could be due to several factors such as poor brake design or maintenance, too heavy of a load, driving at speeds that are too high, not allowing adequate time/distance to reduce speed, fires, or poor roadway conditions. It is expected that any time a person jumps from a piece of equipment they are likely to be injured. However, these injuries may be preventable through the design of equipment (e.g., breaking mechanisms).

The majority of injuries were fractures/chips or sprains/strains. While fractures typically heal nicely and have no residual negative effects, some sprains and strains, particularly of the low-back, can increase risk of future incidents. A sprain or strain may also result in permanent damage to soft tissue structures such as stretching of ligaments. This can make an individual more susceptible to dislocations or other joint injuries. It also makes sense that the individual body parts associated with the highest frequency of injury were the back, shoulder, knee, and ankle since these joints are often strained or sprained. According to the National Safety Council's, 2007 edition of *Injury Facts* (National Safety Council, 2007), the cost (medical and indemnity combined) of individual injuries to the low back, shoulders, knee, and ankle were $21,367, $21,120, $18,495, and $12,518, respectively for occupational injuries in 2003-2004. Based on the number of injuries to these joints demonstrated by this analysis, it can then be estimated that these injuries accounted for more than $6.5 million during 2006 and 2007 in the mining industry.

Several limitations should be discussed. These analyses were conducted using only two years of injury data; thus, it is assumed that these two years are representative of recent years. These analyses also relied heavily on injury narratives, which are often vague and may be interpreted differently by multiple individuals. This limitation was minimized by having multiple reviewers agree on the categorization of each narrative. Also, only reportable instances where a mine worker fell from equipment were considered since the MSHA injury database was utilized for these analyses. Thus, this study did not consider the total frequency that individuals fell from equipment. Instead, only those instances where an injury resulted are investigated. Finally, the lack of exposure data necessary to compute relative risks should be noted. Computing relative risks may change the ranking of research priorities; however, this is a common limitation of studies that evaluate administrative databases. These data are often not recorded, or the overall exposure data cannot be parsed to calculate specific rates (e.g., hours per type of equipment).

5. Conclusions

The majority of fall from equipment injuries (>60%) occur at surface mining facilities and typically involve large trucks, wheel loaders, dozers, and conveyors/belts. Nearly 50% of injuries occur during the ingress/egress process, with most during egress. Injuries are also frequently associated with maintenance tasks. Common injury types include fracture/chip and sprain/strain and the individual body parts most commonly affected are the back, shoulders, knees, and ankles. The severity of injury is independent of age and the median days lost is seven days; however, there is a large range in severity, which was nearly a full year in some cases.

From the data obtained in this study, several different research areas have been identified for future work, which include balance and stability control when descending ladders, equipment design for maintenance tasks, and methods to adequately maintain control of heavy duty equipment.

6. Disclaimer

The findings and conclusions in this study are those of the authors and do not represent the views of the National Institute for Occupational Safety and Health.

Acknowledgments

This project was funded by the National Institute for Occupational Safety and Health.

References

Bjornstig, U., & Johnsson, J. (1992). Ladder Injuries: Mechanisms, Injuries and Consequences. *Journal of Safety Research*, *23*, 9—18.
Bloswick, D. (1999). Climbing Biomechanics. In S. Kumar (Ed.), *Biomechanics in Ergonomics* (pp. 335—349). London: Taylor & Francis.
Bloswick, D., & Chaffin, D. (1990). An Ergonomic Analysis of Ladder Climbing Activity. *International Journal of Industrial Ergonomics*, *6*, 17—27.
Bloswick, D., & Crookston, G. (1992). The effect of Personal, Environmental and Equipment Variables on Preferred Ladder Slant. In S. Kumar (Ed.), *Biomechanics in Ergonomics* (pp. 1015—1020). London: Taylor & Francis.
Bureau of Labor Statistics. (2008). [Data file] Received from http://www.bls.gov/iif/oshwc/osh/case/osnr0031.pdf
Cham, R., & Redfern, M. (2001). Lower Extremity Corrective Reactions to Slip Events. *Journal of Biomechanics*, *34*(11), 1439—1445.
Chang, W. -R., Chang, C. -C., Matz, S., & Son, D. (2004). Friction Requirements for Different Climbing Conditions in Straight Ladder Ascending. *Safety Science*, *42*, 791—805.
Chang, C. -C., Chang, W. -R., & Matz, S. (2005). The effects of Straight Ladder Setup and Usage on Ground Reaction Forces and Friction Requirements during Ascending and Descending. *Safety Science*, *43*, 469—483.
Dewar, M. (1977). Body Movements in Climbing a Ladder. *Ergonomics*, *20*(1), 67—86.
Fathallah, F., & Cotnam, J. (1998). Impact Forces during Exit from Commercial Vehicles. *Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting, Chicago, IL*.
Fathallah, F., & Cotnam, J. (2000). Maximum Forces Sustained during Various Methods of Exiting Commercial Tractors, Trailers, and Trucks. *Applied Ergonomics*, *31*, 25—33.
Fathallah, F., Gronqvist, R., & Cotnam, J. (2000). Estimated Slip Potential on Icy Surfaces during Various Methods of Exiting Commercial Tractors, Trailers, and Trucks. *Safety Science*, *36*, 69—81.
Giguere, D., & Marchand, D. (2005). Perceived Safety and Biomechanical Stress to the Lower Limbs when Stepping Down from Fire Fighting Vehicles. *Applied Ergonomics*, *36*, 107—119.

Hakkinen, K., Pesonen, J., & Rajamaki, E. (1988). Experiments on Safety in the Use of Portable Ladders. *Journal of Occupational Accidents*, *10*, 1—19.

Hammer, W., & Schmalz, U. (1992). Human Behavior when Climbing Ladders with Varying Inclinations. *Safety Science*, *15*, 21—38.

Hoozemans, M., de Looze, M., Kingma, I., Reijneveld, C., de Korte, E., van der Grinten, M., et al. (2005). Workload of Window Cleaners using Ladders Differing in Rung Separation. *Applied Ergonomics*, *36*, 275—282.

Jacobson, J., Redfern, M., Furman, J., Whitney, S., Sparto, P., Wilson, J., et al. (2001). *Balance NAVE: a Virtual Reality Facility for Research and Rehabilitation of Balance Disorders.*

Kane, R., Ouslander, J., & Abrass, I. (1994). *Essentials of Clinical Geriatrics.* New York: McGraw Hill.

Kowalk, D., Duncan, J., & Vaughan, C. (1996). Abduction-Adduction Moments at the Knee during Stair Ascent and Descent. *Journal of Biomechanics*, *29*(3), 383—388.

McIntyre, D. (1983). Gait Patterns during Free Choice Ladder Ascents. *Human Movement Science*, *2*, 187—195.

Mine Safety and Health Administration. (2007). *[Data file] Injury Database.* Washington, DC: Author.

Murphy, P. L., Sorock, G. S., Courtney, T. K., Webster, B. S., & Leamon, T. B. (1996). Injury and Illness in the American Workplace: A Comparison of Data Sources. *American Journal of Industrial Medicine*, *30*(2), 130—141.

National Institute for Occupational Safety and Health. (2008). *Mining Facts - 2006.* Washington, DC: Author.

National Safety Council. (2007). *Injury Facts* (pp. 55). Itasca, IL: Author.

Partridge, R., Virk, A., & Antosia, R. (1998). Causes and Patterns of Injury from Ladder Falls. *Academic Emergency Medicine*, *5*(1), 31—34.

Patenaude, S., Marchand, D., Samperi, S., & Belanger, M. (2001). The effect of the Descent Technique and Truck Cabin Layout on the Landing Impact Forces. *Applied Ergonomics*, *32*, 573—582.

Randolph, R. (1997). Safety Analysis of Surface Haulage Accidents - Part 1. *Holmes Safety Association Bulletin May-June 1-7*.

Redfern, M., & DiPasquale, J. (1997). Biomechanics of Descending Ramps. *Gait & Posture*, *6*, 119—125.

Redfern, M., Jennings, J., Martin, C., & Furman, J. (2001). Attention Influences Sensory Integration for Postural Control in Older Adults. *Gait & Posture*, *14*(3), 211—216.

Redfern, M., Yardley, L., & Bronstein, A. (2001). Visual Influences on Balance. *Journal of Anxiety Disorders*, *15*(1–2), 81—94.

Redfern, M., Moore, P., & Yarsky, C. (1997). The Influence of Flooring on Standing Balance among Older Persons, Human Factors. *Journal of the Human Factors and Ergonomics Society*, *39*(3), 445—455.

Redfern, M., Muller, M., Jennings, J. R., & Furman, J. (2002). Attentional Dynamics in Postural Control during Perturbations in Young and Older Adults. *Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, *57*, B298—B303.

Schlesinger, A., Redfern, M., Dahl, R., & Jennings, J. R. (1998). Postural Control, Attention and Sleep Deprivation. *NeuroReport*, *9*(1), 49—52.

Shepherd, G., Kahler, R., & Cross, J. (2006). Ergonomic Design Interventions - A Case Study Involving Portable Ladders. *Ergonomics*, *49*(3), 221—234.

Wiehagen, W., Mayton, A., Jaspal, J., & Turin, F. (2001). An Analysis of Serious Injuries to Dozer Operators in the U.S. Mining Industry. *DHHS (NIOSH) Publication No. 2001-126.* Washington, DC: National Institute for Occupational Safety and Health.

Yang, B., & Ashton-Miller, J. (2005). Factors affecting Stepladder Stability during a Lateral Weight Transfer: A Study in Healthy Young Adults. *Applied Ergonomics*, *36*, 601—607.