An Analysis of Injuries to Haul Truck Operators in the U.S. Mining Industry

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Because haul trucks are used extensively in mining, the operators of these trucks are exposed to various risks and hazards inherent to this occupation. The objective of this work was to profile injuries sustained during haul truck operations, to identify priorities for further investigation, and to determine potential injury prevention strategies. Data from the Mine Safety and Health Administration (MSHA) annual administrative database were sorted and reviewed to select records identifying a subset of injuries sustained during haul truck operations. Records covering a 5-year period (2004–2008) involving haul trucks were reviewed. The majority of the injury records were for injuries classified as "struck against moving object" (STRUCK) (N=613) and "slip or fall of person from an elevation or on the same level" (SLIPFALL) (N=359). Each injury narrative was read to determine the activity being performed during the injury (such as ingress, egress, driving, maintenance), the incident results (such as operator impact and truck impact), contributing factors to the event, and environmental factors. The nature of the injury, body parts affected, as well as lost work days were also quantified. The average lost work days for STRUCK and SLIPFALL injuries was 60 and 62, respectively. The majority of the total incidents resulted in sprain and strain injuries; the back was the most frequently injured body part injured. For STRUCK injuries, the majority of activities being performed at the time of the injuries involved driving (63%). More than one-third of the total incidents resulted in vertical jarring of the haul truck (36%), and the majority of the total incidents caused jolting and jarring to the operator (75%). For SLIPFALL injuries, the majority of incidents occurred during egress from the vehicle (46%), and of the total incidents, 32% resulted in the worker falling. Almost one-third of the total incidents were due to the operator's foot slipping (32%). Further investigation should focus on the factors contributing to haul truck operators being struck against a moving object and those related to operators slipping and falling.

INTRODUCTION

The operation of earth-moving equipment often contributes to prolonged and high magnitude vibration exposure. Haul trucks are used extensively in mining, and the operation of these trucks is characterized by repetitive tasks such as driving while exposed to whole-body vibration (WBV). Exposure to WBV and the postural requirements of the job have been identified as important risk factors in the development of musculoskeletal disorders of the spine among workers (Kittusamy & Buchholz, 2004; Kittusamy, 2002; Bovenzi & Zadini, 1992; Johanning, 1991; Bongers, Boshuizen, & Hulshof, 1988; Bongers, Hulshof, Dijkstra, & Groenhout, 1990).

Haul truck operations are also characterized by non-repetitive tasks such as exiting the cab to change a filter or clean a window. During some maintenance activities that operators perform (as in the latter example), there is a risk of the worker falling off of equipment. According to a National Institute for Occupational Safety and Health (NIOSH) analysis of Mine Safety and Health Administration (MSHA) nonfatal, lost-time injuries between 2002 and 2006, slip and fall of a person accounted for 25% of mining injuries (NIOSH, 2008). In the Spanish mining sector, just over 17% of serious or fatal accidents were caused by "people falling down at different levels" (Sanmiquel, Freijo, Edo & Rossell, 2010). Some of these falls from equipment occur while entering or exiting equipment via ladders or stair systems. However, factors contributing to these falls are largely unknown.

Once an incident (whether it be an accident, injury, or illness) has occurred, the information that is documented regarding the incident is a valuable source. This information leads to better understanding of the circumstances or causes of the incident, thereby allowing the use of methods (i.e., engineering controls, administrative controls, or personal protective equipment) to protect from and prevent further incidents that are similar in nature. The purpose of this work was to profile and describe injuries sustained during haul truck operations and to identify priorities for further field investigation and any potential injury prevention strategies.

METHODS

MSHA provides an annual administrative database containing all reportable injuries, illnesses, and fatalities sustained in mining. MSHA regulations (30 CFR 50.20) require mine operators and contractors to file a Mine Accident, Injury and Illness Report (MSHA Form 7000-1) for each accident, occupational injury, or occupational illness that occurs at a mine site. This comprehensive data set was sorted and reviewed to select records that identify the injuries sustained during haul truck operations or by haul truck operators during tasks related to maintenance.

Injury Record Selection

Records were chosen from the MSHA injury, illness, and fatality database if the incident:

1. occurred between January 1, 2004 and December 31, 2008
2. involved the operation of a haulage truck on mine property (both surface mines, including coal preparation and minerals processing plants, and underground mines) by mining company employees or contractors to perform a common production task
3. resulted in either
    a. a fatality
    b. permanent, partial, or total disability
    c. days away from work only
    d. days away from work and restricted activity
    e. days of restricted activity only

Injury records from the MSHA database were selected based on the above criteria. This strategy yielded a data set of 1,382 records. Cross tabulations of *accident type* by *accident injury/illness* classification for all records were examined. Two subgroups of injury classification accounted for 70% of the data set and were identified as needing further analysis. All other subgroups accounted for less than 12% of the data set and were not further examined. The injury subgroups that were not included in the final analysis included: 1) overexertion, 2) handling materials, 3) powered haulage, and 4) machinery. The records retained for the final analysis were those where the: 1) *accident type* was classified as "struck against moving object" (STRUCK) (N=613); and 2) *accident injury illness* were classified as "slip or fall of person (from an elevation or on the same level)" (SLIPFALL) (N=359).

Coding of the Records

In order to have a better understanding of the injuries sustained, all of the injury narratives[1] were manually coded and reviewed individually by two of the researchers (BRS and WLP). A classification system was used to code information contained in the narrative. The development of the classification system was adapted and modified from Wiehagen, Mayton, Jaspal and Turin (2001) and Moore, Porter and Dempsey (2009). A list of variables, and various descriptor categories associated with each variable, are described in the following two paragraphs.

Struck against moving object. A total of five variables were used: 1) activity, 2) truck impact, 3) operator impact, 4) contributing factors to the event, and 5) contributing events to the severity. ***Activity*** was defined to code the task being performed by the haul truck operator at the time of injury, such as driving, loading or unloading[2] of the haul truck, or performing maintenance. The ***truck impact*** describes what happened to the haul truck, such as fallover/rollover/fall into void, struck by an object, struck an object, or vertical jarring. The ***operator impact*** describes what happened to the operator, such as having been jolted and jarred, struck by an object, or having sustained a musculoskeletal injury (MSI). ***Contributing factors to the event*** offered information that may have contributed to the occurrence such as an edge or slope failure, hidden void (e.g., potholes), or equipment failure. ***Contributing events to the severity*** were used for cases where information was reported about factors that may have either enhanced or decreased the severity of the injury, such as whether the operator was wearing a seatbelt or not, or if the operator was thrown out or jumped out of the cab.

Slip or fall of a person. Four variables were used: 1) activity, 2) operator impact, 3) contributing factors to the event, 4) environmental factors. ***Activities*** included ingress, egress, performing maintenance, or regular driving operations. The ***operator impact*** described what happened to the operator, such as fell, slipped (with and without falling), or sustained an MSI. ***Contributing factors to the event*** offered information that may have contributed to the occurrence such as equipment failure, foot got caught or slipped, lost balance, lost hand grip, or missed a step. ***Environmental factors*** reported poor environmental conditions that may have contributed to the event such as wet, icy, or muddy conditions.

Once the narratives were read and analyzed by the two reviewers (BRS and WLP), the narratives with discordant coding were determined. Subsequently, all discrepancies were resolved through discussions between the two researchers and a third team member (AGM).

Statistical Analysis

Descriptive statistics were calculated for the MSHA database variables and the coded variables discussed above.

RESULTS

The majority of the workers injured were males STRUCK: males [n=546, 89%], females [N=67, 11%]; SLIPFALL: males [N=338, 94%], females [n=21, 6%]. Table 1 summarizes the demographic information of the injured haul truck operators analyzed for this analysis. For simplicity, the results for both genders have been grouped together.

Table 1: Demographic information of injured haul truck operators. Mean (Standard Deviation)

	STRUCK (N=613)	SLIPFALL (N=359)
Age (years)	40 (13)	41 (14)
Lost work days	60 (75)	62 (78)
Current job experience (weeks)	567 (967)	564 (821)
Total experience this mine (weeks)	493 (1101)	404 (718)
Total mining experience (weeks)	602 (937)	766 (1016)

[1] Narratives are short summaries prepared by an individual at the mine site completing the MSHA Form 7000-1.
[2] The driver was not performing the actual loading and unloading. The driver was in the haul truck as these tasks were performed by others.

Struck Against Moving Object

More than one-half of the injuries sustained were sprains and strains (Table 2). Other injuries (not listed in Table 2) were also reported (e.g., concussion, cuts, lacerations, puncture, joint inflammation); however, each of these only accounted for less than 2 percent of the total injuries.

Table 2: The nature of "struck against moving object" injuries (number and percentage) (N=613)

	N	%
Sprain/strain	340	56
Unclassified, not determined	65	11
Contusion, bruise	63	10
Fracture, chip	59	10
Multiple injuries	37	6
Cut, laceration, puncture	30	5

The most frequently injured body part was the back (N=221, 36%), followed by multiple body parts (N=137, 22%), the neck (N=82, 13%), and shoulder(s) (N=43, 7%). Injuries to other body parts were also reported; however, each of these accounted for less than 4 percent of the total injuries.

Based on the coding of the narratives, almost two-thirds of the injuries occurred while the operator was driving (either in the forward or backward direction), followed by loading then unloading (Table 3). For 5 percent of the narratives, the activity was unknown (N=28) and for less than 5 percent of the narratives (N=14), other activities were being performed (not shown in Table 3). An example of a narrative where "other" was coded for the activity is:

"*When loader operator picked up the hauler to set it off the rock [which rolled under the hauler], the bucket slipped, shaking the hauler and employee."*

Table 3: Activity being performed while injury was sustained (N=613)

	N	%
Driving (forward)	229	37
Loading	137	22
Driving (unknown direction)	97	16
Driving (backward/reversing)	60	10
Unloading	48	8

Slightly more than one-third of the incidents causing injury resulted in vertical jarring of the haul truck (N=218, 36%) occurring mainly during loading and driving (forward) activities. Twenty-eight percent resulted in the haul truck falling/rolling over or falling in a void (N=171), with the majority occurring while driving in the backward direction. Incidents also resulted in collisions with other vehicles (N=57, 9%). For a small percentage of the total incidents, there was no apparent impact to the haul truck (N=44, 7%) or it was unknown whether or not there was any impact to the haul truck (N=36, 6%).

In terms of the impact to the operator, three-quarters of the total incidents resulted in jolting and jarring of the operator (N=461). Of these (jolting and jarring injuries), 12% resulted in the operator striking against an object inside the cab (N=74). Almost one-fifth of the total incidents resulted in an MSI (N=115) and the operator impact was unknown for 6 percent of the total incidents (N=35).

Forty-three percent (N=264) of the narratives did not offer any information regarding the contributing factors to the event. Just over one-quarter of the incidents had the contributing factors classified as "other" (N=164). An example would be:

"While returning to the pit area employee fell asleep. Equipment crossed over a window, causing the operator to be knocked around … causing injury …"

Other contributing factors to the event that were noted were equipment failure (N=80, 13%) and hidden voids (e.g., potholes) (N=57, 9%).

The contributing factors to the severity of the event was largely coded unknown (N=574, 94%) and it was indicated for only approximately 5 percent of the total number of incidents whether or not the operator was wearing a seatbelt (N=32).

Slip or Fall of Person (from an elevation or on the same level)

As with the "struck against moving object" injuries, the most common "slip or fall of a person" nature of injury was sprains/strains (Table 4). Other injuries (not listed in Table 4) each accounted for less than 5 percent of the total injuries.

Table 4: The nature of "slip or fall of a person" injuries (number and percentage) (N=359)

	N	%
Sprain/strain	151	42
Fracture, chip	87	24
Unclassified, not determined	43	12
Contusion, bruise	42	12
Multiple injuries	17	5

The back was the most frequently injured body part (N=64, 18%), followed by the knee (N =49, 14%), multiple body parts (N =41, 11%), ankle (N =39, 11%), shoulder(s) (N =34, 10%), and chest (N =19, 5%).

The coding of the narratives revealed that almost one-half of the incidents occurred during egress from the vehicle and almost one-quarter occurred during ingress (Table 5). Sixteen percent (N=58) of these injuries occurred during maintenance activities. A small percentage was classified as either being "other" or "unknown." An example of a narrative where "other" was coded for the activity is:

"Employee did not have hold of hand hold that was provided to enable him to have 3 point contact."

Table 5: Activity being performed while injury was sustained (N=359)

	N	%
Egress	165	46
Ingress	81	23
Maintenance	58	16
Other	27	8
Unknown	20	6

Approximately one-third of the total incidents resulted in the operator falling (either forward or backward) (N=115, 32%) and approximately one-quarter resulted in slipping and falling (N=94, 26%). The incidents also resulted in the operator sustaining an MSI (N=90, 25%) and slipping (but without falling) (N=50, 14%).

The contributing factors to the event are summarized in Table 6. The majority of the contributing factors were due to the foot slipping, and a large proportion of factors were unknown. Other contributing factors not listed in the aforementioned table each only accounted for less than 3 percent of the total incidents.

Table 6: Contributing factors leading to an event (N=359).

	N	%
Foot slipped	116	32
Unknown	86	24
Other	30	8
Lost footing/slipped	27	8
Equipment failure	24	7
Missed step	22	6
Lost hand grip/hand slipped	20	6

Environmental factors were noted for 11% of all incidents (N=40). Wet, icy, and muddy conditions were each only indicated for less than four percent of the incidents.

DISCUSSION

Injuries sustained during haul truck operations were analyzed in order to identify priorities for further investigation and potential injury prevention strategies. Injury records with *accident type* classified as "struck against moving object" and *accident injury illness* classified as "slip or fall of person (from an elevation or on the same level)" accounted for a large proportion (70%) of the total injuries recorded between 2004 and 2008.

For the "struck against moving object" injuries, the majority occurred while the operator was driving the haul truck and the majority of operators sustained back injuries. Further investigation showed the impact to the haul truck was primarily vertical jarring while driving in the forward direction, thus causing jolting and jarring to the operator. The primary factor contributing to these vertical jarring events were hidden voids (e.g., potholes) that were noted on the haul roads. Driving in the backward direction, however, resulted in different outcomes. A large number of injuries resulted in haul truck rollovers, fallovers, or falling into hidden voids. The contributing factors to these types of incidents were largely unknown. However, equipment failure (e.g., axle housing separating, tire rod breaking) was identified as a contributing factor. Another factor contributing to a large proportion (38%) of these types of incidents (i.e., driving backwards resulting in the haul truck rolling over) was the operator having fallen asleep. Given the long work duties and possible night shifts, driver fatigue and sleepiness are possible. In 1995, a major truck and bus safety summit meeting identified driver fatigue as the primary truck safety issue (Truck & Bus Safety Summit, 1995). Methods to better identify these components in haul truck operators could help prevent such incidents.

More than 60% of the total injuries related to "slip or fall of person (from an elevation or on the same level)" occurred during egress and ingress, with the majority during egress. This concurs with previous work that has shown a large proportion of injuries having occurred during ingress or egress of large mining vehicles (Moore, Porter & Dempsey, 2009; Randolph, 1997). The major contributing factor to these incidences is foot slipping. Therefore, reasons why these incidences occur, whether it is due to the operator's decreased sense of awareness of surroundings or environmental conditions (although our analyses did not demonstrate this) are topics for further investigation.

In 2001, Turin, Wiehagen, Jaspal, & Mayton reported similar findings in an examination of haul truck injuries relative to dump site safety between 1988 and 1997. Three primary haul truck activities were selected: stationary dumping, backing up, and moving forward. Greater than 90% of the serious injuries occurred during stationary dumping and backing up. Most frequently, injuries resulted from the haul truck falling over an edge while backing up, the operator being bounced and/or jarred while dumping, and the haul truck rolling over while dumping. Moreover, injuries were evaluated by effects on the operator, and by haul truck activity. For effects on the operator, "struck against object" accounted for more than one-half of all serious injuries, including seven fatalities. For haul truck activity, the researchers reported that for just under one-quarter of the total injuries, the result was the operator "bouncing or jarring." The researchers highlighted safe work practices relevant to haul trucks backing up and stationary dumping. These practices included devices such as cameras or proximity detection to assist drivers at dump points during backing up, or having the haul truck dump short with dozer assistance to push the pile over the edge. Other best practices include ensuring that a thorough preoperation inspection becomes a habit; mud, grease, or ice is cleaned off boots and ladders; and seatbelts are used. In summary, it is important to highlight these best practices and encourage mines to develop and maintain a comprehensive risk reduction strategy, which is key to enhancing haul truck dump site safety and efficiency.

This descriptive analysis of MSHA injury data related to injuries sustained during haul truck operations found that the majority of injuries were classified as resulting from "struck against moving object" or "slip or fall of person from an

elevation or on the same level." After reading through the narratives, we were able to identify contributing factors to the events, the impact on the truck and operator, and environmental factors leading to the incidents. These all lead to better understanding of the circumstances of the injuries, to encourage the development of controls (e.g., engineering, administration) to reduce the frequency and severity of such injuries, and to prioritize areas for further investigation. However, methods of reporting such injuries in the MSHA database could be incomplete, and they also vary from one person to another. Therefore, an in-depth task analysis and additional field investigations should be carried out to fully understand injuries related to haul truck operations.

DISCLAIMER

The findings and conclusions in this paper 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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