Slips Trips and Falls in Northern Ontario Underground Hard-Rock Mines

by

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A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Human Kinetics (MHK)

The Faculty of Graduate Studies
Laurentian University
Sudbury, Ontario, Canada

THESIS DEFENCE COMMITTEE/COMITÉ DE SOUTENANCE DE THÈSE
Laurentian Université/Université Laurentienne
Faculty of Graduate Studies/Faculté des études supérieures

Title of Thesis Titre de la thèse	Slips Trips and Falls in Northern Ontario Underground Hard-Rock Mines
Name of Candidate Nom du candidat	Sherrington, Chelsea
Degree Diplôme	Master of
Department/Program Département/Programme	Human Kinetics
Date of Defence Date de la soutenance	August 05, 2020

APPROVED/APPROUVÉ

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ACCESSIBILITY CLAUSE AND PERMISSION TO USE

Abstract

Underground mining environments are dark, wet, and have uneven terrain that can create a risk for slips, trips, and falls (STFs). Ontario hard-rock mine workers are legally required to wear personal protective equipment (PPE). Underground miners also work in a dark and dusty environment with uneven terrain, many work shiftwork, and many work on or around large equipment. There is limited research on STFs in underground mining (Dobson et al., 2015) and to my knowledge workers in underground hard-rock mines have not been surveyed about their perceptions of STF risk factors

This study was conducted to advance understanding of risk factors for STFs in underground mines in Northern Ontario, with an aim to provide recommendations for underground safety guidelines, training procedures and future research. 152 underground workers from 2 mine sites in Northern Ontario completed a survey regarding STF in underground mining. The survey contained 16 open-ended and 6 closed-ended questions that addressed demographics, working roles, and perceptions of STF risk factors pertaining to personal, environmental, work task and PPE related factors. Closed-ended questions were coded and analyzed in SPSS. Open-ended questions were analyzed using the Braun and Clark. (2019) method of thematic analysis.

The top 10 identified risk factors included uneven terrain, puddles/holes, poor lighting, slippery surfaces, fatigue, getting in/out of equipment, clutter in the walkway, poor vision, walking long distances, and poor balance. Workers identified work environment as the primary component of STF risk, as 5 of the top 10 risk factors indicated are a sub-set of environmental factors. When asked what contributed to the risk of STF 29 of 152 underground workers

discussed housekeeping and maintenance of roadways. 54.6% (n=83) of workers strongly agreed that climbing on/off equipment was also a major risk factor for STFs and ranked it 6 out of 10. Workers also identified fatigue as a risk factor as it was ranked 5 out of 10. 54% (n=82) agreed and 30.3% (n=46) strongly agreed that their personal level of fatigue was a risk factor for STFs. Responses indicated that 80.9% (n=123) and 52% (n=79) of workers felt that they were more likely to experience a STF towards the end of their shift and beginning of their shift respectively. Workers also indicated that they aware of the risk factors in their workplace as 59.3% strongly agreed to this statement.

Future research on the top 10 identified risk factors (uneven terrain, puddles/holes, poor lighting, slippery surfaces, fatigue, getting in/out of equipment, clutter in the walkway, poor vision, walking long distances, poor balance) would be beneficial to further understand how each factor affects a worker's risk of experiencing a STF.

Keywords

Slips, Trips, Falls, Underground Mining, Mining, Hard-rock Mining, Northern Ontario

Acknowledgments

First and foremost, I would like that thank my supervisor Dr. Tammy Eger for the opportunity to learn and grow through the pursuit of my Master's degree. Working alongside Dr. Eger has taught me a great deal more than just how to properly conduct research. With her guidance I have learned what it means to put out the best work possible, work as part of a team and make academic information available to all regardless of their background. Thank you, Tammy, for providing me with the tools to better myself personally and professionally through conferences, access to the CROSH community and so much more. Thank you for your continuous support and leadership through this process.

I would also like to thank my committee members. Thank you to Dr. Alison Godwin for providing guidance throughout the entire process and for providing me with many opportunities to learn and present outside of my thesis. Thank you to Dr. Bruce Oddson for guiding me through the unfamiliar territory of statistical analysis. Thank you to Peg Scherzinger for her encouragement throughout the creation and interpretation of the survey. I am very grateful to have had the opportunity to work alongside all of you and could not have completed my thesis without your support and guidance.

Thank you to Brandon Vance who continuously encouraged me to push through times of difficulty. Thank you for getting up early to help me with on-site data collection. Your encouragement and advice for each on-site visit helped to develop my presentation skills. You were always there to answer my hundreds of questions when I wasn't sure what to do next or didn't understand a concept. Thank you for celebrating the little accomplishments with as much enthusiasm as me. I can't thank you enough for your friendship and all the support that came with that.

To Mallorie Leduc, I have so much to thank you for. You have helped me not only with my Master's degree but with my professional career as well. Thank you for proof reading presentations and posters and for helping me navigate Laerd. You have helped me improve my presentation skills and my professional communication by providing me with as many resources as you could find.

Thank you to the CROSH lab as a whole for providing me with a space to be productive and create new friendships. A specific thanks to Kimberly Friesen and Margarete Kanya-Forstner for always being there to put a smile on my face, listening to my rants, and constantly encouraging me to do my best. Your friendship has helped me more than words can describe. The lab would not have been the same without our desks all together. The support and environment of the CROSH lab was a critical in the completion of my Master's degree.

Thank you to Vale for allowing me to come onsite to complete data collection. Thank you to the Goodman School of Mines and William Shaver for the scholarships I received. They were instrumental in giving me time to complete my degree.

Finally, I would like to thank my family and friends for your support. Thank you to my mom, dad and sister for listening to all of my frustration and for letting me talk about all of the things that probably didn't make sense to you at the time. Thank you for always making sure I had every opportunity to succeed. To my boyfriend Tommy, thank you for being there for me no matter what I needed. Thank you for always being interested in my work and supporting me through the exciting and stressful times. I love you and could not have done this without you!

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Terminology and Definitions

Hazard: a source of potential damage, harm or adverse health effects on something or someone.

Risk factor: something that increases risk or susceptibility.

Risk: A chance or probability that a person will be harmed or experience an adverse health effect if exposed to a hazard.

Severity: describes the highest level of damage possible when an accident occurs from a particular hazard.

Probability: likelihood of an event occurring.

Hard-rock mine: Mining that takes place in igneous and metamorphic rock by means of drilling and blasting to extract the ore.

Introduction

1 Introduction

1.1 Mining Basics

Underground hard rock mining is a method of retrieving minerals, precious metals, gems and diamonds. Mines are developed by blasting into hard rock to obtain ore. Working conditions in underground mines can be unpredictable and are often poorly lit making them dark, wet with water and puddles on the ground and slippery (Dobson, Riddiford-Harland, Bell, & Steele, 2017a). Underground mines can vary from being extremely hot due to the rock temperature to extremely cold during the harsh winters in colder climates (CCOHS, 2018). Working sections of the mines are constantly changing as new areas are blasted and as the ground conditions change. Areas that were previously free of debris or dry could change following a blast which would change the hazards present (MOSH, 2018).

Underground mining is carried out by electricians, heavy machinery operators, geologists and maintenance workers. Mine layouts can require workers to walk a great distance over uneven ground with falling debris, unexpected puddles, inclines and declines. Workers are also required to ingress and egress from equipment (Dobson, Riddiford-Harland, Bell, & Steele, 2017b).

Personal protective equipment (PPE) is required for all underground mining jobs. The requirements in northern Ontario underground mines include high visibility coveralls with reflective striping, hard hat, gloves, cap lamp, safety belt, and industrial work-boots (Occupational Health and Safety Act, R.R.O. 1990, Reg, 854, Part IV). The work-boots must be made of either leather or rubber and must have a high shaft to protect the shank. Work-boots

must also contain a steel or composite toe plate and internal metatarsal guard. The cumbersome PPE and unpredictable conditions in underground mines in combination with a large amount of time spent walking in clunky work-boots may contribute to an increased risk of slips, trips, and falls (Dobson et al., 2017a).

1.2 Slips Trips and Falls

According to the Ministry of Labour (2015) slips, trips and falls (STF) are one of the leading causes of lost-time workplace injuries. In Canada more than 42,000 workers are injured due to a fall per year. According to the Canadian Centre for Occupational Health and Safety, STFs account for about 18% of the lost time injuries accepted by workers' compensation in Canada (CCOHS, 2019). In Northern Ontario about 40% of lost time injuries at a mining company were sprain and strain related injuries and about 41% of lost time injuries at another northern mining company were due to bodily motion or work conditions (WSIB Compass, 2017). Both of these types of injuries could be caused by STFs or a STF could be a contributing factor. Moreover, lost-time claims in the mining industry due to falls have increased from 11% in 2014 to 16% in 2017 (Workplace Safety North, 2018). Furthermore, lost time claims do not include the injuries that were not reported, or did not lead to any time off work. Lost time claims for acute and chronic foot, knee, hip and back pain that underground miners experience may also be caused by a STFs or a STF could have contributed to the pain (Dobson et al., 2015).

The first step to assessing a potential risk in any workplace is to identify the hazards (CCOHS, 2017). Once a hazard is identified a risk assessment can be performed to identify who is at risk, the likelihood of harm and the severity of that harm. The risk assessment can then be used to determine controls and actions required to mitigate or eliminate the hazards (CCOHS,

2017). The aim of this study is to identify underground workers' perceptions of hazards related to STFs in underground hard-rock mines.

1.3 Purpose

Although underground miners spend a good part of their working life in an underground mining environment there has not been very much research regarding STFs in this industry. A Web of Science search of the key words; underground, hard-rock, mining, slips, trips, and falls results in 0 articles. Due to the lack of research little is known about STF hazards that are present in underground mining. Moreover, statistics have shown that STFs are common causes of lost time claims and injuries (as presented in section 1.2); however, causes of those STFs in underground hard-rock mines remain unknown in the academic literature.

The overall purpose of this research was to understand risk factors that contribute to STF in Northern Ontario underground hard-rock mines. Relevant literature on STFs is presented in Chapter 2; including environmental, work-task, personal protective equipment, and personal factors. The methodology used to address the research questions will be presented in Chapter 3 followed by the results in Chapter 4 and discussion in Chapter 5. The research ethics approval letter for this study along with copies of the consent form and survey in English and French is provided in the Appendices.

Literature Review

2 Literature Review

A slip is defined as a slide suddenly or involuntarily (Oxford English Dictionary, 2019), and occurs where there is not enough friction between the foot/footwear and the walking surface (CCOHS, 2018). A trip is defined as a verb that means to stumble (Oxford, 2019), and occurs when a person's foot comes in contact with an object causing a loss of balance (CCOHS, 2018). A fall is defined as a sudden uncontrollable descent (Oxford, 2019), and occurs from a height or on the same level. While STFs have been researched in a variety of industries, the research done in relation to the mining industry is minimal. However, the risk factors identified in similar industries such as firefighting and construction may be present in mining. Some of the identified risk factors present in industrial workplaces include personal, environmental, personal protective equipment (PPE) and work task factors. The available research on these areas will be presented in the following subsections.

2.1 Slips, Trips and Falls

In the context of occupational health and safety a fall is often preceded by a slip or trip (Lipscomb et al., 2006) from same level or a fall from a height. Same level falls can be caused by slippery or uneven terrain, tripping hazards, or unsuitable footwear. Falling from heights is categorized by a fall from an object or platform three or more meters high (WSPS, 2019). While most of the falls that will be discussed in this dissertation are related to same level falls, to protect the informants of this study falls will not be separated by height or same level. According to the Canadian Centre for Occupational Health and Safety (2018), 67% of falls occur on the

same level. The remaining fall incidents occur from heights, which include but are not limited to falls from roofs, ladders, stairs, and ingressing/egressing from equipment (CCOHS, 2018). Approximately 80 workers are injured in a fall every day (Workplace Safety North (WSN), 2019). In 2019, 14,974 lost time claims in Ontario were due to falls.

Fall related injuries account for 23% of all lost time claims in Ontario in 2019 (WSIB by the Numbers, 2019). Fall related claims account for 21% of lost time claims in 2019 in the Greater Sudbury area specifically (WSIB by the Numbers, 2020). According to the Workplace Safety and Prevention Services (WSPS) (2019), in Ontario, the lost time claims due to falls will cost a total of $249 million over the life of the claims and can cost a business around $59,000 per injury. The highest frequency of fall related claims in Ontario in 2018 were in the construction, health care and manufacturing industries (WSIB by the Numbers, 2019). A total of 9242 fall related claims came from the construction industry while the mining and forestry industries had 285 and 238 claims respectively. Furthermore, Greater Sudbury has the second highest percentage of fall related claims in Ontario mining at 8%, while Cochrane has the highest percentage of fall related claims in mining at 10% (WSIB by the Numbers, 2019).

2.2 Slips, Trips and Falls in Industrial Workplaces

2.2.1 Construction

STFs are the leading cause of injury in the construction industry (Bentley *et al.* 2006). When working in the construction industry there are often multiple trades working in close proximity to one another (Lipscomb et al., 2006) and each trade may create a different hazard for each other. For example, debris left by one worker that obstructs pathways of another can create a tripping hazard, and dust from various materials used by a worker can impair visibility of

another worker (Bentley et al., 2006). Dust can also decrease the coefficient of friction which can create a slipping hazard (Lipscomb et al., 2006). Debris and dust can be difficult to control due to changing dynamics on a construction site. Therefore, education on hazard awareness is important in preventing STFs as knowing the hazards may help change the way a worker preforms a task (Bentley et al., 2006).

Lipscomb et al. conducted a study in 2006 that evaluated the injuries preceded by a slip or trip during the Denver International Airport construction. Following their evaluation they found that 58% of all falls were preceded by a slip or trip, and 70.8% of injured workers slipped and 23.3% tripped (Lipscomb et al., 2006). The dominant injuries were sprains/strains as a result of a slip without a fall. Slips without falls more commonly caused injuries to the lower extremity while falls from same level or from heights were associated with injury to the back and trunk. Furthermore, a great deal of STFs occurred while transferring from one place to another and descending or ascending stairs (Lipscomb et al., 2006). Tasks that required divided attention such as transitioning from a ladder or stairs and required balance and attention were reported to increase the risk of STFs (Bentley et al., 2006).

The construction industry also requires lifting heavy and awkwardly shaped objects. This can become a risk for STFs because of the awkward shape or carrying position of the object can cause workers to adopt improper postures and obstruct a workers view (Lipscomb et al., 2006). The awkward posture may also affect a worker's balance which could increase their risk of a STF. All of these factors are present in hard-rock underground mines and may contribute to STF risk.

2.2.2 Firefighting

Firefighters, like miners, are required to wear PPE in order to protect them from workplace hazards. While firefighting PPE differs from underground mining PPE, it may pose some of the same risks when evaluating STFs. Work-boots for mining and firefighting are heavy and protect the foot from being punctured. Both professions also require hard hats, cap lamps, as well as, tool/miner's belts. Some miner's may also wear a self-contained breathing apparatus (SCBA) for technical tasks. Firefighters are required to carry heavy equipment and walk on potentially slippery and uneven ground in an environment where vision may be reduced (Kong et al., 2013). For firefighters it was estimated that STFs make up approximately 25% of their injuries.

Physical fitness was also shown to be a predicting factor for the level of risk of STFs. In the United States firefighters have a greater BMI at the beginning of their career than other countries (Kong et al., 2013). This may lead to more frequent falls because of decreased muscle strength and changes in balance due to weight distribution. Extended periods of walking in heat and the heavy PPE has been found to increase a number of changes in the gait cycle which increases the likelihood of a fall (Kong et al., 2013).

Carrying heavy or awkward equipment may also contribute to the risks that firefighters encounter in the workplace. Similar to workers in the construction industry, firefighters are required to carry heavy equipment and water hoses. This may change the worker's posture, which may alter the worker's gait (Kong et al., 2013). The SCBA that firefighters wear may be one of the major risk factors for falls. Firefighters with SCBAs are more likely to experience a fall compared to firefighters without SCBA (Hallemans et al., 2009). Kong et al (2013) suggests that the weight of the SCBA can have an effect on the worker's balance causing an increased risk

of fall related incidents. The SCBA may also cause impairments to the visual field which hinders workers from making the appropriate postural adjustments to avoid falls. Therefore, it is suggested that it is not the SCBA itself that causes the falls but rather its effect on a worker's visual field and balance (Kong et al., 2013). Moreover, firefighters were found to walk slower as a way to maintain balance when wearing the SCBA (Park et al., 2015). The variability in firefighting has been shown to make mitigating the risk of falls challenging. Extended exposure to heat and heavy equipment, as well as, the uneven ground are all factors that vary on a daily basis (Kong et al., 2013).

2.2.3 Mining

Underground miners, oil and gas drillers, and related workers accounted for 22% of fall claims in the Ontario Mining Industry in 2017 (WSIB By the Numbers, 2019). The Greater Sudbury basin is home to a total of 8 active underground hard-rock mines (Ontario Mining Association, 2020) which equates to approximately 20% of the active underground mines in Ontario (Ontario Mining Association, 2020). Therefore, it is not surprising that the Greater Sudbury area also has the highest percentage of the fall claims in the Ontario Mining industry since 2011. In 2017, Greater Sudbury accounted for 19% of all fall claims in the Ontario Mining industry (WSIB By the Numbers, 2019). These statistics indicate that STFs due to a variety of factors are in fact a problem in the underground mining workplace.

Personal factors such as decreased awareness, fatigue, poor vision and poor balance may also influence a worker's STF risk. Awareness of one's surroundings could help the worker avoid environmental hazards such as deep puddles, and debris in the walkway. It may also be important to discourage rushing to avoid sudden changes in the environment. While these

hazards have been identified in the research for other industries, they have yet to be evaluated in the mining industry.

Dust and limited lighting are environmental factors that contribute to poor visual fields in underground mines. These are potential factors that could lead to an increased risk of STFs. Other environmental factors present in underground mining include; debris in the walkway, uneven and slippery terrain, and deep puddles. While some factors may be controlled, for example, lighting and placement of work materials, others such as, terrain, dust levels and water levels are unpredictable due to the dynamic nature of a mine (Dobson et al., 2017b). The environmental and personal factors coupled with other risks such as workplace factors may significantly increase a worker's risk of injury due to a STF.

Work task factors found to be hazardous in other industries such as climbing ladders and ingressing/egressing from equipment are also present in underground mines. Workers may be required to climb stairs or ladders to access the appropriate work area. Workers may also be required to operate equipment from which they will mount and dismount. Although no research was found that evaluated the risk of work task factors in underground mines and STFs, these factors are documented risks in the construction industry as discussed in section 2.2.1 (Lipscomb et al., 2006). This indicates that work task factors may increase workers' risks of STFs.

Previous research has shown that underground coal miners are not satisfied with their required work-boots (Dobson et al., 2018). However, little research has evaluated the relationship between PPE and STFs in underground hard-rock mines. It is known that firefighter PPE poses a risk for STFs (Kong et al., 2013). Although mining PPE is slightly different there are enough similarities that miners may be at an increased risk of STFs due to their PPE. Of the research conducted in the mining industry it has been shown that work-boot weight, shaft height

and stiffness cause changes to the normal gait pattern which increases a worker's risk of STFs (Dobson et al., 2017b).

2.3 Slips, Trips and Falls Risk Factors

Common workplace hazards for STFs include; slippery surfaces, changes in walkway levels and slopes, snow and ice, poor lighting, falls from trucks or trailers, debris in the walkway, smoke/dust, poorly maintained equipment and unsuitable footwear (Ministry of Labour, 2018). All of the factors listed could occur in Northern Ontario underground hard-rock mines. This may explain why these workers are at an increased risk of STFs.

2.3.1 Personal Factors

Personal factors such as poor vision, poor balance and fatigue can be risk factors for STFs at work (Dobson et al., 2017b). These factors are contributors to a larger risk factor which is hazard awareness. Lack of visual or environmental stimulus such as seeing an obstructed pathway or sensing uneven ground via the feet would decrease hazard awareness; therefore, reducing a worker's ability to avoid the hazard or mitigate their risk (Bentley et al., 2006). Similarly, fatigue may contribute to a worker's ability to observe hazards reducing their likelihood of behaving in such a way that will prevent STFs (Dobson et al., 2017b).

Furthermore, a worker's attention while on the worksite can be a contributing factor to the risk of STFs. Bentley et al. (2006) suggested that worker's divided attention between two visual tasks at the same time was a common risk factor for STFs. This is because the worker's balance is affected while their attention is divided. The effects of divided attention on balance can be exacerbated by environmental factors such as uneven terrain (Bentley et al., 2006).

Age may also be a contributing factor to the risk of STFs. Kemmlert & Lundholm (2001) found that STF incidents were more frequent among workers age 45 years and older. It was also noted that older workers took longer sick leave following an incident (Kemmlert & Lundholm, 2001). Kong, Suyama, & Hostler (2013) suggested that postural sway increased with age which may be a cause for the increased STFs seen in the over 40 year old age category. Chang, Leclercq, Lockhart, & Haslam (2016) have described age as being a risk factor when older workers are affected by age related changes such as a fitness level, balance and strength. It was also noted other research has not found a relationship between age and risk of STFs. Therefore, more investigation is needed to determine if age is a risk factor for STFs in the mining industry.

2.3.2 Environmental Factors

Wet or slippery surfaces, occasional spills, weather hazards such as; snow and ice, loose rugs or mats and flooring or other walking surfaces that lack the same degree of traction in all areas are all risk factors for slips that can lead to a fall (CCOSH, 2018). Obstructed view, poor lighting, cluttered pathways, uneven terrain, fog, poor lighting and uncovered cables are risk factors that increase the likelihood of a trip that can lead to a fall. These risk factors are all likely to be present in an underground mining environment (Dobson et al., 2017b). Due to the unpredictable nature of the underground mining environment some risk factors will change on a daily basis, which requires workers to be aware of potential hazards at all times (Bentley et al., 2006).

Chang, Leclercq, Lockhart, & Haslam (2016) found that underfoot surfaces could be a hazard for STFs. More specifically, obstacles on the ground, a collapse of the ground and slippery surfaces were shown to be factors that contributed to a STF event. A collapse of the

ground underfoot was shown to be the most common factor to initiate a fall. Poorly maintained workspace was also noted as a risk factor for STFs (Bentley et al., 2006).

Uneven terrain has been shown to alter heal strike phase and pre-swing phase of the gait cycle (Dobson et al., 2017b). These phases may be affected when there is a change in terrain such as an obstruction on the ground or uneven walkway as the worker must compensate for the difference in underfoot ground. An increased heel strike velocity may occur if a portion of the ground is elevated as the foot will reach the ground sooner than expected. This is indicative of an increased risk of slips due to improper foot placement (Dobson et al., 2017b). The pre-swing phase will be affected when there is an obstruction in the walkway as the worker will be required to lift the foot higher in order to avoid the obstruction. Both of these situations will change the normal gait cycle, which will increase the risk of STFs (Dobson et al., 2017b).

2.3.3 Work Task Factors

Ingressing/egressing from machinery, and climbing stairs and ladders are tasks that increase the risk for STFs (CCOHS, 2018). These tasks require balance and awareness of the terrain below. Jumping from equipment may also increase the risk of falling (CCOHS, 2018). When working on elevated platforms proper training is required along with safety belts or harnesses to prevent falling from heights. Lack of training and safety equipment may increase a worker's risk of falls from heights (WSPS, 2018).

Among New Zealand construction workers, ladders, scaffolding and roofs were shown to be the most common origin for falls from a height while slips were shown to be the most frequent event to initiate an event (Bentley et al., 2006). The choice of climbing device can affect a worker's risk for STFs. Kemmlert & Lundholm (2001) report that the majority of STF incidents from a height were due to an improper choice of climbing device for the task.

Furthermore, planning and organization of work such as; equipment choice, scheduling, and time pressure have been shown to change worker behavior, which can lead to an increased risk of STFs (Bentley et al., 2006).

2.3.4 Personal Protective Equipment Factors/Footwear

To date there has been little research conducted that evaluates the relationship between PPE and STFs. The majority of research regarding PPE has been conducted with firefighters or evaluated the risks due to the lack of PPE in underground mining while very little has evaluated the hazards associated with wearing the PPE. However, the research conducted with firefighters has shown that PPE is a risk factor in relation to STFs (Kong et al., 2013). Of the research that evaluates PPE and STFs in the mining industry the majority of the focus has been on the work-boots (Dobson et al., 2017b).

While there is more literature that focuses on underground mining work-boots than other pieces of PPE, the overall research that evaluates footwear and STFs underground is minimal. A great deal of research has been carried out to evaluate the relationship between STFs and general footwear. In a study of footwear characteristics and falls in older people Menz, Morris, & Lord (2006) found that balance and gait patterns could be impaired when wearing the wrong footwear for the task. Menz et al. (2006) found that most outdoor falls in older adults occurred when walking on uneven ground or stepping up onto an object. Very few STFs occurred when walking on a flat surface such as a street. This is an indicator that the uneven underground terrain may be a contributing factor to the risk of STFs.

Menz et al. (2006) also suggest that poor fitting shoes may increase the risk of injury. This finding is relevant in underground mines as the required footwear should be appropriate for the task and the right fit in order to prevent STFs. Heel height, tread and sole thickness and hardness

all affect gait patterns (Menz et al., 2006). The tread and sole thickness and hardness have been shown to affect the coefficient or friction which then affects a person's risk of slip related falls. The heel height has been shown to affect a person's balance where the higher the heel the more difficult it is to balance (Menz et al., 2006). The most hazardous slips tend to occur following the initial heel strike (Chander et al., 2017). This is due to the position of the foot and ankle joint during this phase of the gait cycle. The body reaction during a slip affects the outcome of the slip. The conditions present during the initial post heel strike have been shown to influence the outcome of the slip. Chander et al (2019) found that footwear characteristics such as; boot shaft height, mass, heel elevation etc. can affect balance and gait. These factors will affect the risk of slips. This indicates that specific footwear characteristics can affect a person's risk of STFs. While there is some research on mining footwear characteristics there is a great deal more on athletic footwear characteristics and STF. Some of the findings from athletic footwear studies could be applied to understanding the risks with mining footwear.

2.3.4.1 Athletic Footwear

In a study conducted on slip initiation in slip resistant footwear Chander et al. (2017) concluded that a shoe that allows the participant to closely follow a normal barefoot gait pattern is the safest. This is because the footwear that allowed for the most normal gait also allowed proper foot placement when walking on slippery surfaces (Chander et al., 2017). Many of the studies conducted regarding footwear type and elderly STFs have used semi-structured interviews and focus groups like the ones conducted by Menz, Morris, & Lord (2006) and Yardley, Donovan-Hall, Francis, & Todd (2006). Conclusions drawn from these studies indicate that footwear characteristics do have an impact on the risks of STFs. Sherrington & Menz (2003) also concluded that there is a relationship between fall type and footwear type. The authors note

that footwear characteristics that increase the risk of falling include; excessively flexible heel counters and heel height, as well as, a narrow heel. Sherrington & Menz (2003) also note that insufficient anti-slip outer soles will increase the risk of slipping. They also show that environment has an effect on the type of footwear that should be worn (Menz et al., 2006).

Many of the characteristics discussed in the research conducted using alternative shoes are similar to work-boots characteristics, such as anti-slip tread, flexibility of the sole, ankle support, and heel height. Therefore, these same methods may be useful in qualitatively assessing underground footwear. It is important to assess both footwear characteristics and worker satisfaction with the work-boots, as well as environmental conditions.

2.3.4.2 Industrial Footwear

Lace-up boots (figure 1) or slip on muckers (figure 2) are typically worn in Northern underground hard-rock mines. Both boots contain a metal or composite toe plate and internal metatarsal plate to protect the top of the foot, while Lace-up boots are typically made of leather and have a high shaft that can be tightened by worker. Muckers are made of rubber with a high shaft that fits loosely after pulling the boots on. Both boots protect the shank by having a high shaft. In 2015 Dobson et al. showed gait was affected when wearing mining boots; however it is remains unclear in the research as to the exact cause for the change in gait. Moreover, the authors went on to suggest the gait changes could be associated with an increased risk for STFs.

Figure 1 – Example leather lace up boot worn by underground miners.

Figure 2 – Example rubber "muckers" worn by underground miners.

Work-boot characteristics including sole flexibility, shaft heights, shaft support, and boot weight have been quantitatively assessed under simulated work environments (Chiou et al., 2012; Dobson et al., 2017b). Common measures used to assess differences in the types of boots include range of motion, muscles activity, and joint angles (Böhm & Hösl, 2010). The most studied phases in gait when examining work-boots has been the initial heel contact velocity and the toe clearance during the pre-swing phase. These two measures were described by Dobson et

al. (2017b) as helpful in understanding slip and trip hazards in relation to the work-boots. An increased heel strike velocity is indicative of an increased risk of slip related falls because the greater velocity can cause improper placement of the heal during initial contact. The decreased toe clearance during the pre-swing phase is indicative of an increase in trip related falls. This is because the less room there is between the toe and the ground the more chance there is of hitting the toe on the ground causing a trip (Dobson et al., 2017b).

While examining the literature on industrial footwear Dobson et al. (2017b) found that the shaft height of a boot greatly affected the range of mothing (ROM) of the ankle. After studying male and female firefighters Park et al. (2015) concluded that boots with a higher shaft restricted ankle ROM by decreasing the amount of plantar-flexion and dorsi-flexion at the ankle. Dobson et al. (2017b) notes that these are essential movements for proper gait. Restricting them could increase the risk of slips and trips due to decreased toe clearance during pre and mid swing, as well as, increased heal strike velocity during initial contact. The heel strike phase of the gait cycle sets up proper foot placement; therefore, improper heel strike will lead to improper foot placement thus contributing to the slip related fall (Chander et al., 2017). Dobson et al. (2017b) suggests that many of the characteristics of industrial work-boots alter the normal gait pattern. More specifically, shaft height and stiffness affect ankle ROM and stability, which affects the push-off and pre-swing phases of the gait cycle (Dobson et al., 2017b). The weight of the work-boot is also a concern as it requires more muscle force when walking (Dobson et al., 2015). This can lead to fatigue which would also alter the gait pattern. Moreover, alteration of the normal gait cycle can lead to stumbling and falling

Park et al. (2015) also found that the boots with a higher shaft allowed for increased ankle inversion and eversion range of motion and went on to say the lack of inversion-eversion

support in the firefighting boots could lead to an increased risk of lateral ankle sprains. However, Simeonov et al. (2008) suggested that the relationship between shaft height and ankle stability is situation dependent. The authors also found no significant difference in ankle support in boots with a higher shaft and suggested the support may come from the mode of attachment. Therefore, lace-up boots may provide more support than slip on boots because of the adjustable nature of the attachment.

While lace-up boots tend to provide more ankle support they may also have a stiffer shaft. Böhm & Hösl (2010) found a stiffer shaft to be problematic for hip biomechanics. In decreasing the range of motion at the ankle with a stiffer shaft the body compensated by increasing the hip range of motion. This is an area of disagreement in the literature as many others have seen no significant difference in hip range of motion with changing shaft stiffness (Dobson et al., 2017b). Boot mass may also play a role in ankle stability and range of motion as this factor was not controlled in any of the studies mentioned above.

Furthermore, most of the research done on footwear in underground mines has been conducted in Australia with coal miners. To my knowledge no footwear related research has been conducted in underground hard-rock mines in North America. Therefore, it is unknown if the results of research done in Australia is generalizable to Canadian underground mines.

Boot characteristics such as; thick soles, material (leather or rubber), steel or composite toe plate and internal metatarsal guard can lead to an increase in boot weight. These features are typically required in underground mining footwear. Chiou et al. (2012) conducted a study evaluating boot mass with male and female firefighters. This study lead to the conclusion that boot mass affected heel contact velocity and toe clearance which can caused a greater

acceleration downward during initial contact and pre-swing which lead to an increased risks of slip or trip related falls (Chiou et al., 2012).

Heavier boots were shown to require more muscle activity (Dobson et al., 2015; Kim et al., 2015) leading to an increased oxygen consumption (Chiou et al., 2012). Kim et al. (2015) suggests that the increased activity in the thigh is required to allow for a normal gait pattern. Lifting a foot with more weight on it would require more force, which could lead to the increased thigh muscle activity that was found in the previously mentioned studies. This compensation could be done to maintain sufficient toe clearance during the pre and mid swing phases. However, this speculation has not yet been confirmed.

The increased muscle activity and metabolic demands required when wearing heavier work-boots could also lead to an increased rate of fatigue (Dobson et al., 2015). After studying 20 male underground coal miners Dobson et al. (2015) found that there was increased muscle activity in the lower limb when wearing lace-up boots compared to the mucker style boots. This result was unexpected as the lace-up boots provide more ankle support than the mucker style boots. Dobson et al. (2015) attributes this result to the increased weight of the lace-up boot. It is suggested in the same study that the increased muscle activity would lead to the workers becoming fatigued faster. When workers become fatigued the risk of slip and trip related falls can increase as the gait pattern changes (Dobson et al., 2015).

Dobson et al. (2017b) also found that while most studies made conclusions about different footwear characteristics such as; sole flexibility, boot type, shaft height, etc. none of the studies controlled for boot mass. This could be an underlying factor in the results obtained when studying other individual boot characteristics. Dobson et al. (2015) notes this as a limitation of the research done on lower limb muscle activity of underground coal miners in Australia.

2.3.4.3 PPE Satisfaction Surveys

Few surveys have been conducted assessing satisfaction with workers' PPE. To the author's knowledge the only known surveys that assess mining PPE focused solely on the work-boots. Surveys by Marr (1999) and Smith, Harris, Harris, Truman, & Pelham (1999) had similar results to a more recent survey done by Dobson, Riddiford-Harland, Bell, & Steele (2018). These surveys only assessed the worker's pain occurrence and whether or not they attributed this pain to their work-boots, as well as, their overall work-boot satisfaction. To the authors knowledge there has been no research that assessed workers' thoughts as to how their work environment and work-boots may contribute to their discomfort and the risk of STFs.

A great deal of the research conducted has used objective measures to assess the characteristics of industrial footwear and how it affects a person's gait; however, few studies have considered worker's opinions and satisfaction with their footwear. In 1999, Smith et al. and Marr (1999) conducted research to see if workers were satisfied with their work-boots. These studies found that underground coal miners were not satisfied with their work-boots and that their footwear was not suitable for the job requirements. Over one third of miners indicated that their injuries were caused by their work-boots (Smith et al., 1999). Dobson et al. conducted a follow up survey in 2018 that assessed workers satisfaction with their work-boots. The survey was given to 355 men and 3 women in underground coal mining and assessed work-boot satisfaction, job details, foot, lower limb and back pain. Most jobs required a great deal of walking and muddy, uneven and slippery ground was common. Most workers reported that work-boots were uncomfortable or as being indifferent and a contributing factor to STFs (Dobson et al., 2018). The type of pain reported differed depending on the type of surface that was worked on. Miners working on muddy surfaces reported having more general foot and hip

pain while miners working on hard ground reported having more dry skin and heel pain. Miners working on slippery surfaces reported pain in the ball of the foot more than any other surface (Dobson et al., 2018). These data collected by Dobson et al. (2018) indicates that there is further research required in this field as workers believe that their work-boots are a contributing factor to their discomfort and risk of falls.

With fall related injuries on the rise in the underground mining industry, there is a need for more research in this area (Workplace Safety North, 2017). Little research has been done in the underground mining industry to evaluate the risks of STFs. Furthermore, most of the known research regarding the risk of STFs in occupational settings has been conducted in construction or firefighting industries. However, statistics demonstrated that STFs were a leading cause of injuries resulting in a lost-time claim in the mining industry (WSIB by the Numbers, 2020). This is a strong indication that research is required in the area of STF and underground hard-rock mining.

2.4 Study Purpose

Based on findings reported for STFs in other industrial workplaces, risks for STFs in the underground hard-rock mining workplace could include; environmental factors (wet, dark, uneven terrain etc.), work task factors (ingressing/egressing from equipment, climbing ladder and stairs), PPE factors (work-boot shaft height, sole flexibility, boot weight), and personal factors (situational awareness, fatigue, poor vision, impaired balance). Previous research has also reported underground coal miners in Australia were not satisfied with their required footwear and attributed their injuries and pain to their work-boots (Dobson et al., 2018). To the author's knowledge no previous research has been conducted in Northern Ontario underground hard-rock

mines on risk factors associated with STFs. Therefore, the overall purpose of this study was to advance the understanding of risk factors for STFs in underground hard-rock mines in Northern Ontario, with the aim to provide recommendations for underground safety guidelines and work-boot design. Through qualitative and quantitative methods underground miners' perceptions of STF hazards were solicited to 1) determine the top 10 risk factors for STFs, 2) determine if risk factors varied by job type, 3) determine if reported STFs varied by work-boot type, and 4) determine if workers recommended changes to work task factors, environmental factors, personal factors or PPE factors to decrease STF risk. Findings from this study will be used to provide recommendations to decrease the risk of STFs in underground hard-rock mines and to provide design recommendations to improve equipment, PPE including mining work-boots.

3 Methods

Ethics approval was obtained from the Laurentian University Research Ethics Board (Appendix A). Selection of mine sites and participants, survey protocol and questions, data analysis and storage are discussed.

3.1 Mine Site Selection

To recruit mine sites a member of the research team reached out to representatives from two major mining companies in the Sudbury area. One mining company agreed to have two of their mine sites participate in the study. Members of the research team met with representatives from the joint health and safety committee at each mine site to review study requirements and discuss the process to recruit participants. The participating mine sites agreed to have members of the research team attend the worksite to invite workers to participate in the study and complete a survey on STFs during paid worktime. Workers who had experience working underground in a hard-rock mine were invited to participate in the study. Workers at the participating underground mines typically worked 12-hour shifts days and nights on a rotating schedule; therefore, members of the research team attended mine site 1 twice and mine site 2 three times in an effort to maximize the opportunity for workers to participate.

3.2 Participants

This study used a sample of convenience within the participating work-sites. Participants were recruited, from the participating worksites, by a member of the research team. To

participate in the study workers were required to have experience working in an underground hard-rock mine and be between the ages of 18-65 years. There was no minimum work experience required to participate. Informed consent was obtained from each participant in the form of a signature on the consent form prior to completing the survey. The consent form (Appendix B [English]; Appendix C [French]) contained the purpose of the study, the types of questions in the survey, and clearly indicated participant responses would remain anonymous. Participants were informed that their participation was voluntary and that there would be no repercussions if they withdrew from the study at any time.

3.3 Survey Protocol

Prior to data collection the proposed survey was reviewed by members of the health and safety committee to confirm the survey length was appropriate and the question terminology was correct for an. Underground hard-rock mine. Following the survey review by members of the health and safety committee, participating workers were invited to complete the survey. The survey was available in French and English and typically took between 20-30 minutes to complete. Members of the research team attended the partnering worksites on multiple days to ensure workers across the 5 different work shifts had the opportunity to participate. The survey was distributed in a meeting room on surface at the worksites during normal work hours. The participating miners were given paid time during their shift to complete the survey. Upon verbal agreement to participate in the study, participants were given a package that contained the consent form and the survey. A member of the research team explained that participants had the right to withdraw from the study at any time, or choose to not answer any questions. Participants were then given a numbered envelope that matched the number on their consent form.

Participants were asked to seal the completed survey in their numbered envelope for submission. The envelope numbers were used to code the surveys and consent forms in order to maintain participant anonymity. Completed surveys were collected by members of the research team and locked in a secure file cabinet at the Centre for Research in Occupational Safety and Health.

3.3.1 Survey Questions

The survey (Appendix D: Appendix E) contained 22 questions. There were 6 open-ended questions and 16 closed-ended questions. The questions covered the following topics; demographics such as; age, gender, height and weight; work-task details; PPE; employer supplied or not; work environment; and history of slips, trips and falls (Appendix B). The survey was pilot tested by members of the research team, as well as, workers involved in the mining industry. The survey was given to workers involved in the mining industry, outside of the participating mine sites. Pilot testing confirmed the estimated time to complete the survey and tested comprehension of survey questions. Pilot testing participants returned the completed surveys with notes on questions they had while completing the survey. This feedback was used to finalize survey questions and administration procedures.

The survey was offered in French and English. To generate the French survey, the English survey was translated into French then back translated into English to ensure that the questions were interpreted the same in both languages. Survey translation was performed by an official translator recommended by the Laurentian University Translation Department.

3.3.2 Data Analysis

Survey response data were entered into an Excel spreadsheet where closed-ended questions were coded, and open-ended questions were entered verbatim. Survey data were

analyzed using the methods from Dobson et al. (2018) as a framework where descriptive analysis was used to determine response frequency and percentages and relationship analysis was performed for significant variables. For this study on STF risk the closed-ended questions were coded and counted, and a thematic analysis was performed on the open-ended questions.

3.3.2.1 Quantitative Analysis

A descriptive analysis was performed using SPSS and histograms for each variable were generated. The relationship between STF frequency and walking frequency, boot type or location was assessed using a spearman correlation. A post-hoc binomial logistic regression was performed to evaluate the relationship between position, age, or experience and reported STF or combination incident with any outcome. The top 10 risks for STF as reported by the workers were obtained by assigning points for each ranked answer where a ranking of 1 was awarded the most points and a ranking of 10 or higher was awarded the least points. The points were summed for each variable and the 10 variables with the most points were put in a table from most points to least.

3.3.2.2 Qualitative Analysis

The Braun and Clark method for thematic analysis outlined in the Handbook of Research Methods in Psychology (Chapter 4, 2019) was used to analyze qualitative data. The 6 open-ended questions were read individually to obtain a high-level of familiarity with the data required to analyze for subthemes (Braun et al., 2019). The responses were then read, and key words recorded as codes for each response. The codes were grouped into categories which were then grouped into subthemes and the subthemes were then grouped into overall themes (Braun et al.,

2019). The themes were reviewed and compared against the codes to ensure the quality of the themes and that they made sense for the question. Each theme was then given a name. Lastly, the subthemes and overall themes were reported in a manner that maintained the highest level of participant anonymity. The responses were analyzed to evaluate the number of times each theme was discussed, for each of the open-ended question. This was done in order to evaluate which theme was most identified as a risk factor for STF. The quantitative and qualitative data was read through to identify each risk factor, and the total number of times it was indicated by participants throughout the entire survey.

Results

4 Results

4.1 Participants

The survey was given to workers with experience working in an underground hard-rock mine in Northern Ontario. 150 male and 2 female workers between the age of 18-65, participated in the study. Given the small number of female participants, male and female responses were combined. Participants included drillers, operators, mechanics, supervisors, support miners and others (Table 1). The average height, mass, and years of experience of the participants were 179.58cm (±7.59), 94.62kg (± 17.81), 11-20 years (±1.11), respectively.

Table 1-Number of workers in each position.

Position	Number of Participants
Drillers	30
Operators	31
Mechanics	39
Supervisors	10
Support Miners	24
Other (Bolter, loader, etc.)	18

Work tasks that were required for some of these positions are driving/ operating equipment, supervising workers, servicing and maintaining equipment, ventilation, water

services, etc., drilling and ground support. Walking, lifting, handling material, welding, bolting, scaling and applying shotcrete are just some of the actions that workers described as being required to complete their daily work tasks (full description by position in Appendix G).

4.1.1 Demographics, Experience and Position

An ordinal regression identified no relationship between height, weight, and reported STF frequency. Similarly, there was no relationship found between STF frequency and the worker's position. A post-hoc binary regression indicated that age, gender and experience were not a predictor for STF frequency, all zs<1.

4.2 General Risk Factors for STF

Qualitative and quantitative data pertaining to environmental, work-task, PPE and personal risk factors reported are described below (Tables 2-5; Appendix F). Terrain conditions were the most frequently discussed in the open-ended questions. When asked what factors the workers believed contributed to their STF risk, uneven terrain, chunks/muck (rock)/objects on the ground and water/puddles were mentioned 53, 43 and 35 times respectively. When asked to describe any STF incident they had had, workers almost always described a terrain condition as the cause of the incident.

Workers who identified environmental conditions discussed chunks/muck, uneven terrain and slippery surfaces because of mud and/or spills most frequently as the main cause of the incident. 13.76% of workers who discussed environmental conditions as the main cause of their STF incident also report a STF in the last 12 months. A complete list of factors that were

identified along with the number of times each factor was identified (positive response) throughout the survey is provided in Table 2.

There were 3 major themes from the qualitative analysis of the question “What factors do you think contribute to your risk of slips, trips or falls?”. The major themes were environmental, equipment and personal factors (Table 3). There were 2 major themes for the question “In your lifetime what is the worst slip, trip and/or fall event you have experienced while working in an underground mine?”. The major themes were shared with the previously mentioned question and included environmental, and equipment (Table 4). For both questions the most frequently discussed were categories that fell under the environmental theme.

When asked about potential STF risk factors workers discussed the subthemes terrain and housekeeping the most. Lack of proper housekeeping was described as contributing to the poor terrain which then leads to a risk of STF. The subthemes within the equipment theme included; PPE, climbing on/off equipment and condition of the equipment. Worker 32 indicated the following as potential risk factors:

> “Uneven ground. Poor Visibility. Mount/dismount equipment. Fatigue”

Climbing on and off of equipment was the most frequently discussed factor within the equipment theme. The personal factors theme included subthemes such as; attention/ rushing, fatigue, balance and planning. The most frequently discussed categories were attention, rushing and fatigue.

Just as the major themes were similar for the above-mentioned questions, the subthemes for the question about previous STF incident were similar as well. Within the environmental

theme there were categories such as uneven terrain, slippery surfaces, poor housekeeping and water. Workers discussed water as being a problem in combination with uneven terrain as the puddles hide potential tripping and falling hazards. Many of the workers also discussed the environmental factors with the equipment factors. For example, workers described a STF incident as occurring when they were climbing off a piece of equipment and stepped onto a chunk or piece of muck below their foot. Climbing on/off of equipment along with condition of equipment were the most discussed categories within the equipment theme.

Workers identified personal factors such as fatigue (n=260), attention or distraction (n=105) and awareness (n=101) throughout the open and closed-ended questions of the survey. Generally, these factors were discussed in combination with other factors such as; work task or environmental in open-ended questions. As for work-task factors climbing on/off equipment was identified by workers 305 times throughout the survey (Table 2) and was the most identified STF risk factor for the overall survey. These responses indicate an overall summary of responses (Table 2) and the number of responses indicates the total number of times that each factor was identified across the entire survey. Therefore, factors may have been discussed more than once by a participant resulting in the number of identifications being greater than the total number of participants.

Of all the factors PPE was the only one that was not included in the top 10 risk factors for STFs. However, workers did identify some risk factors related to PPE. For example, cap lamps were discussed 182 times throughout the survey responses (Table 2). Workers also identified PPE such as high visibility clothing, protective eyewear and work-boots as factors that increase the risk of STFs.

Table 2 - Summary of risk factors identified by workers. Positive responses indicate a worker identifying a factor as a risk for STF.

Risk Factor	Number of Positive Responses	Risk Factor	Number of Positive Responses
Climbing On/Off Equipment	305	Condition of Work Area/ Travel-ways	31
Fatigue	260	Slip-on Rubber Boots (Muckers)	27
Uneven Terrain	227	General Work-Boots	24
Water/Puddles/ Holes	197	Rushing	20
Slippery Surfaces/Spills	190	Miner's Belt	20
Cap Lamp	182	Lace-up Leather Boots	17
Lighting	175	Hard Hat	15
Hydration	174	Half-face Respirator	11
Clutter/ Muck on Ground/ Equipment	160	Guardrails/ Mounting Rails & Steps	9
Overall Work Environment	158	Communication of hazards	9
Distraction/Attention	105	Shotcrete Helmet	8
Awareness	101	Heat	7
Housekeeping/ Maintenance	99	Overall PPE	6
Poor Vision	90	Carrying materials	4
Walking Long Distances	83	Work Gloves	4
Balance	75	Changes in conditions	4
Protective Eyewear	70	Planning	3
Poor Grip on Work-Boots	64	Shift Work	3
Previous Injury	56	Physical Abilities	3
High Visibility Clothing	51	Heights	2
Work-Boot Weight	43	Age	2
Work-Boot Fit	42		

Table 3 - Thematic analysis breakdown using the method for the question "What factors do you think contribute to your risk of STFs?". The count column refers to the number of times one of the codes was mentioned in a particular subtheme.

Code	Subtheme	Count	Theme
Uneven Terrain Muck/chunks/ Objects on Ground Spill/slippery surfaces Ground conditions/footing Airlines/uncovered cables Water covering ground/puddles	Terrain	190	Environment
Poor housekeeping/planning Housekeeping of road/ walkways Housekeeping of work area Maintenance of water	Housekeeping	55	
Lighting Visibility Dust	Visibility	23	
Heat	Heat	6	
Open drill holes Heights	Open holes/ Heights	5	
Environment overall Changes in conditions Congested work area	Environment	17	
Rushing Attention Fatigue Balance Age Dehydration Physical abilities	Personal	34	Personal factors
Manual work Shift work High walking rate	Work Requirements	5	
Getting on/off equipment Ladders/stairs Equipment condition Mounting bars	Equipment	28	Equipment
Shotcrete Helmet Poor PPE Poor footwear Heavy footwear Coveralls Fall arrest Heavy gear	PPE	11	

Table 4 - Thematic analysis breakdown for responses about previous STF incidents in an underground hard-rock mine. The count column refers to the number of times one of the codes was mentioned in a particular subtheme.

Code	Subtheme	Count	Theme
Uneven ground Slippery conditions Spills Wet Water covering ground/puddles Mud	Terrain	48	Environmental
Dust Visibility Lighting Dark	Visibility	6	
Tools on ground Loose rock Wireline on drill	Clutter on ground	31	
ITH hole Fell down raise	ITH hole/ raise	4	
Holding with one hand Climbing on/off equipment Stairs/ ladder Walking Carrying Equipment	Work Task Factors	47	Equipment
Broken/ not bolted steps Broken railings No hand holds Loose deck	Maintenance of Equipment	5	
Shotcrete helmet Poor boots Boot laces	PPE	3	
No STF Not Reported	No STF	4	No STF

Table 5 - Thematic analysis breakdown for responses about possible STF prevention factors. The count column refers to the number of times one of the codes was mentioned in a particular subtheme.

Code	Subtheme	Count	Theme
Rushing Attention/ Focus Awareness Rest Pride Fatigue More exercise Stress	Personal Factors	36	Personal Factors
More time for tasks Workplace audit Stop and Correct Night shift	Work Related Factors	8	
Housekeeping Wash shop floors Clean up spills Better/ cleaner walk and roadways Maintenance Better cleanup of stopes Clean refuge Better adherence to workplace standard Water Control	Housekeeping/ Maintenance	67	Environmental Factors
Dust Heat Chunks Even ground Better lighting	Environment	31	
Free boots Better boots Proper protective eyewear Better cap lamp/ no cord Remove hard hats in shop Better fitting PPE	PPE	16	PPE Factors
Improper equipment set up Better handrails/ steps	Equipment	9	Work Task Factors
Footing Less walking Less mounting and dismounting Four-point mounting and dismounting	Work Task Factors	8	
Hard in an underground environment Nothing	Nothing	10	Nothing
Employer/ Supervisor listen to workers Communication Training	Communication	6	Communication

4.3 Top 10 Risk Factors

Participants were asked to rank the ten risk factors they believed contribute most to STFs underground. As reported by the workers the top 10 risk factors in order from greatest risk to least amount of risk include; uneven terrain, puddles/holes, poor lighting, slippery surfaces, fatigue, getting in and out of equipment, clutter in the walkways, poor vision, walking long distances and poor balance (Table 6). These responses differ from the top 10 factors in Table 2 which demonstrates an overall summary of the survey responses and Table 6 demonstrates the top 10 risk factors as identified by workers in a singular question. Responses for Table 6 were ranked based on the point system described in Chapter 3.

Table 6- Top 10 risk factors for slips, trips and falls as ranked by the workers. The cumulative points indicate the total number of points each factor scores based on the individual rankings given by each participant (where 10 was given to the risk factor perceived to result in the greatest risk for a STF and 1 to the lowest risk factor). These points were used to determine the overall ranking of each factor.

Rank	Cumulative Points	Risk Factor	Rank	Cumulative Points	Risk Factor
1	1236	Uneven Terrain	6	673	Getting In/Out of Equipment
2	992	Puddles/Holes	7	617	Clutter in the Walkway
3	862	Poor Lighting	8	475	Poor Vision
4	836	Slippery Surfaces	9	423	Walking Long Distances
5	721	Fatigue	10	386	Poor Balance

In the rankings, 5 out of 10 factors in table 6 were environmental factors such as uneven terrain and puddles and/or holes. Uneven terrain and housekeeping were the most discussed

subthemes under the broader environmental theme. Many of the top ten factors were discussed as being due to poor housekeeping and maintenance. Housekeeping was also a major subtheme under the broader equipment theme along with climbing on and off of equipment, which was also one of the top ten risk factors. Four out of top 10 factors reported by the participants to increase risk of STF were personal factors (Table 6). This is also supported through the open-ended responses by the participants which indicated fatigue, balance, and vision as concerns when they were asked to comment on factors that played a role in their STF risk (See Table 3 and section 4.7)

Uneven terrain was given a number 1 ranking 94 times while the factor that ranked second (puddles/holes) was given a number 1 ranking 26 times. While slippery surfaces had fewer overall points than poor lighting and puddles/holes, it was given a number one ranking 29 times.

4.4 Work Environment

Factors pertaining to work environment were the most frequently indicated in the qualitative and quantitative data. The subthemes within the environmental theme included; terrain, lighting, temperature, open holes and housekeeping. Factors such as uneven terrain and puddles/holes were ranked in the top 10 risk factors contributing to STFs, (table 6). Majority of workers described their work environment as dark with poor lighting (n= 122), and hot (n=132) with uneven terrain (n=131). Workers also indicated that their work environment was wet (n=92), slippery (n=97), and dusty (n=24) with loose terrain (n=99). When shown the statement "The work environment contributes to my risk of slips, trips and falls." 62% of workers strongly agreed while 36% agreed and 1.3% disagreed.

Apart from clutter in the walkway, environmental factors were ranked higher than all other factors in the top 10 risk factors as identified by workers (table 6). Uneven terrain was indicated as the primary risk factor for STF underground as reported by the workers. It was also the most reported environmental condition in the underground workplace. 86.2% of workers selected uneven terrain to describe their work environment. Workers also reported that their work environment was slippery. While workers frequently discussed water and slippery surfaces as factors contributing to STFs, not all workers who reported a slippery work environment reported a wet work environment. Slippery was more frequently reported than wet conditions. Workers only reported wet conditions 59.9% of the time while slippery surfaces were reported 63.8% of the time. Therefore, not all slippery surfaces were due to water and mud.

Slippery surfaces were frequently discussed when reporting the conditions of a STF incident. When workers described slippery surfaces as the cause they also described water, mud and spills as being the cause of the slippery surface. For example, worker 3 said:

> "Slippery conditions (slime on the snowbanks) and uneven ground."

Many of the workers described "slime", oil, drilling polymers and grease as causing slippery surfaces that would lead to a STF incident in open-ended questions regarding factors that contribute to STF risk (question 9- appendix d). Workers described spills of oil, slime, drilling polymers and grease more frequently than water as the cause for slippery surfaces.

Water was most often described as a risk factor because of the fact that it can easily hide the uneven terrain below it. When describing previous incidents workers described stepping into a deeper puddle than expected or onto a loose rock or rail that was not visible making it difficult to avoid the hazard. While describing a previous STF incident worker 8 said:

"Very wet drift, walking to my workplaces and I slid on a rail that was under the water"

This is one example. Other workers discussed water as covering unexpected hazards such as loose rock or muck as the cause of a previous STF incident. Worker 86 said:

"Walking off level end of shift walking through water hole. Trip over muck that was under the water, sprain left wrist when I fell."

Workers who discussed water as being a problem often described uneven terrain alongside. Workers described stepping off of equipment or walking down a drift and stepping into a puddle onto an unexpected chunk or sudden change in terrain, which then lead to a STF incident.

4.4.1 Housekeeping and Maintenance

When asked what could be done to prevent STFs, workers said that better housekeeping and maintenance on roads and walkways would be a solution. Similarly, when asked what contributed to the risk of STFs underground workers discussed housekeeping and maintenance of roadways 29 times.

"Proper roadway maintenance and workplace clean up. (P#94)"

All of the above conditions that were described were mentioned in terms of poor housekeeping. Workers indicated that the best way to reduce environmental risks such as uneven terrain, slippery surfaces, puddles and clutter in the walkway would be with better housekeeping. Some examples included better walk and roadway maintenance, water management and cleaning up of the work area upon completion of a task.

4.5 Equipment

54.6% strongly agreed and 40.6% agreed that climbing on and off of equipment was a risk factor for STF (Figure 3). Climbing on/off of equipment was discussed 34 times when describing a STF incident. Workers discussed poor stair condition, and poor hand hold placement.

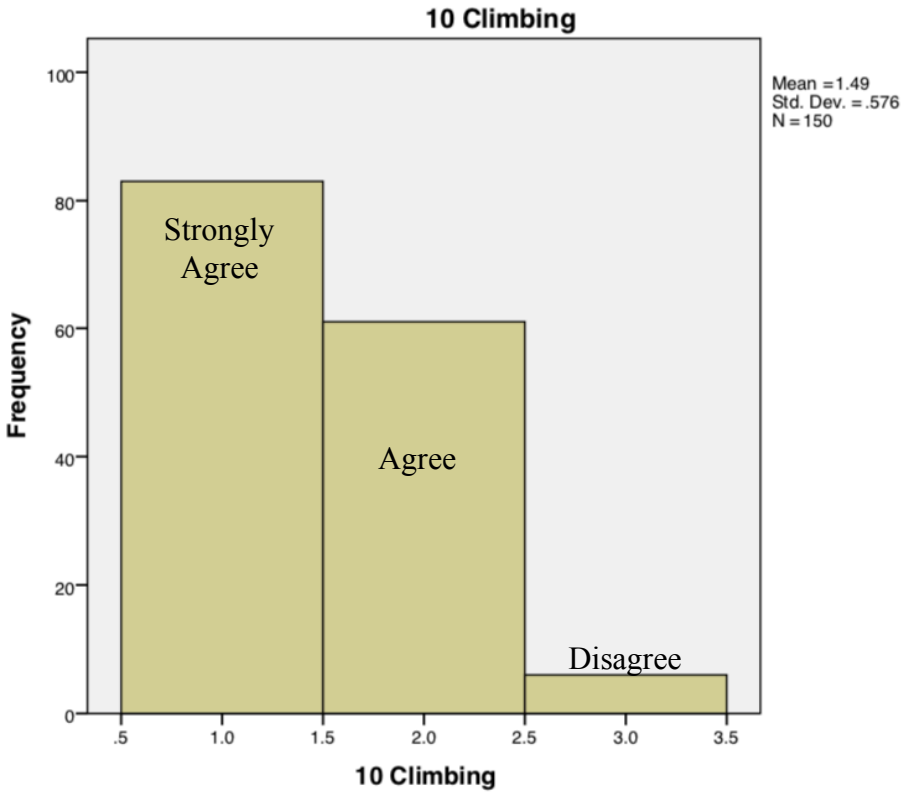

Figure 3- Responses to the statement "Climbing on/off equipment contributes to my risk of STF".

Of all equipment related factors ingress and egress from equipment was most frequently mentioned by workers in the open-ended questions. Discussion of climbing on and off of

equipment was often coupled with discussion of stepping on a chunk or piece of muck (rock) when egressing from the equipment.

> "Twisted ankle dismounting equipment. Not noticing rocks under foot." (P#24)

Workers discussed hand holds being in an awkward place or steps in a poor location as one of the reasons why climbing on/off of equipment is a risk for STF. Workers also discussed spills on the steps and loose steps as a reason why climbing on/off equipment is a STF risk factor.

4.5.1 Housekeeping and Maintenance

Housekeeping and maintenance of equipment were frequently discussed alongside an injury that occurred where the worker identified equipment ingress/egress as the main cause of the incident. Workers provided examples such as a spill on the step or poor vision while egressing from equipment as factors causing their STF incident.

> "Ground was uneven, poor lighting. The steps were not bolted together properly resulting in a tripping hazard causing roll ankle." (P#43).

Similar to the environmental factors, workers discussed better housekeeping as a method for reducing the previously mentioned factors. Beyond mentioning better maintenance on equipment and better placement for handholds workers did not discuss specific methods of how these changes should be made.

4.6 Personal Protective Equipment

48% and 48.7% of workers responded no and yes respectively to the question, “Is there anything you would change about your PPE” and when asked which PPE contributes most to risk of STF 40% of the workers indicated the cap lamps. Almost every participant (97.4%) indicated that their cap lamp had a cord. The next piece of PPE was protective eye wear at 19.1% of workers followed by slip of rubber boots at 17.1% of workers.

Of the workers who responded that they would like to change something about the current PPE, majority of the workers indicated that eliminating the cap lamp cord would be beneficial. When specifically asked about PPE, workers most frequently described cap lamp cords and shotcrete helmets as risk factors.

“Better shotcrete helmet for visibility” (P#7).

“Wireless cap lamp. Cord gets stuck or snagged on things.” (P#22).

PPE was rarely discussed when describing the factors that contributed to a previous STF incident. PPE was a subtheme of the major theme Equipment. Any of the factors within the subtheme of PPE was related to the overall weight of the PPE, ill-fitting PPE, cap lamp cords or shotcrete helmets.

While workers rarely discussed work-boots as a factor for a previous STF incident, poor and heavy work-boots were identified as a factor under the PPE subtheme as potentially contributing to STFs risk. Worker #143 and 90 said:

“Work-boot condition.”

"Heavy footwear"

Quality of the tread, fit, and weight of the work-boots were characteristics that were described as why work-boots were contributing to STF risk. Workers identified slip on rubber boots 27 times, and lace-up leather boots 17 times across the entirety of the survey. However, there was no statistical relationship between STF frequency and work-boot type.

4.7 Personal Factors

The third major theme from the analysis of the question regarding workers' perceived risk factors for STFs was personal factors. This included codes such as attention, fatigue, balance and awareness. Workers indicated that they were aware of the risk factors for STF in their workplace. 59.3% strongly agreed and 39.3% agreed to the statement "I am aware of the risk factors for STF". While heat is an environmental factor; workers rarely indicated that heat was the main cause of an incident or discussed solely heat when discussing potential risk factors. Heat was often discussed alongside other factors such as fatigue, and level of attention. For example, when asked which factors contribute to their risk of STF one worker said;

"Fatigue, heat, uneven and slippery ground. Heat stress, dehydration, not paying attention, or keeping mind on the job, poor footwear." (P#40).

Heat would also play a role in the level of hydration which participants indicated was a factor. When shown the statement "My level of hydration contributes to my risk of STF." 27.5% and 46.3% strongly agreed and agreed respectively while 24.8% disagreed.

4.7.1 Attention, Fatigue and Balance

Fatigue was identified by workers as one of the top 10 risk factors for STF. Responses indicated that 80.3% and 52% of workers felt that they were more likely to experience a STF towards the end of their shift and beginning of their shift respectively. Only 34.9% and 39.5% felt they were more likely to experience a STF just before or after lunch in the middle of the workday. The workers also indicated that fatigue was a personal risk factor for STF with 54% of participants agreeing and 30.6% strongly agreeing to the statement "My level of fatigue contributes to my risk of STF" (Figure 5).

When asked if there was anything else they would like to share about their risk of STF workers most frequently discussed not rushing as a method of preventing STF followed by paying better attention. Similar results were seen in analysis of responses to a question regarding what workers think contributes to their risk of STFs in the underground hard-rock mine workplace. Within the major theme of personal factors, the most frequently discussed categories were rushing to complete tasks (n=10) and lack of attention (n=9) due to a variety of factors. Workers discussed fatigue, rushing, shift work, and dehydration as reasons for the lack of attention when completing a task. Workers also indicated that they felt aware of the STF risk factors in their workplace with 59.2% (n= 90) of workers strongly agreeing to a statement about STF factor awareness (Figure 4).

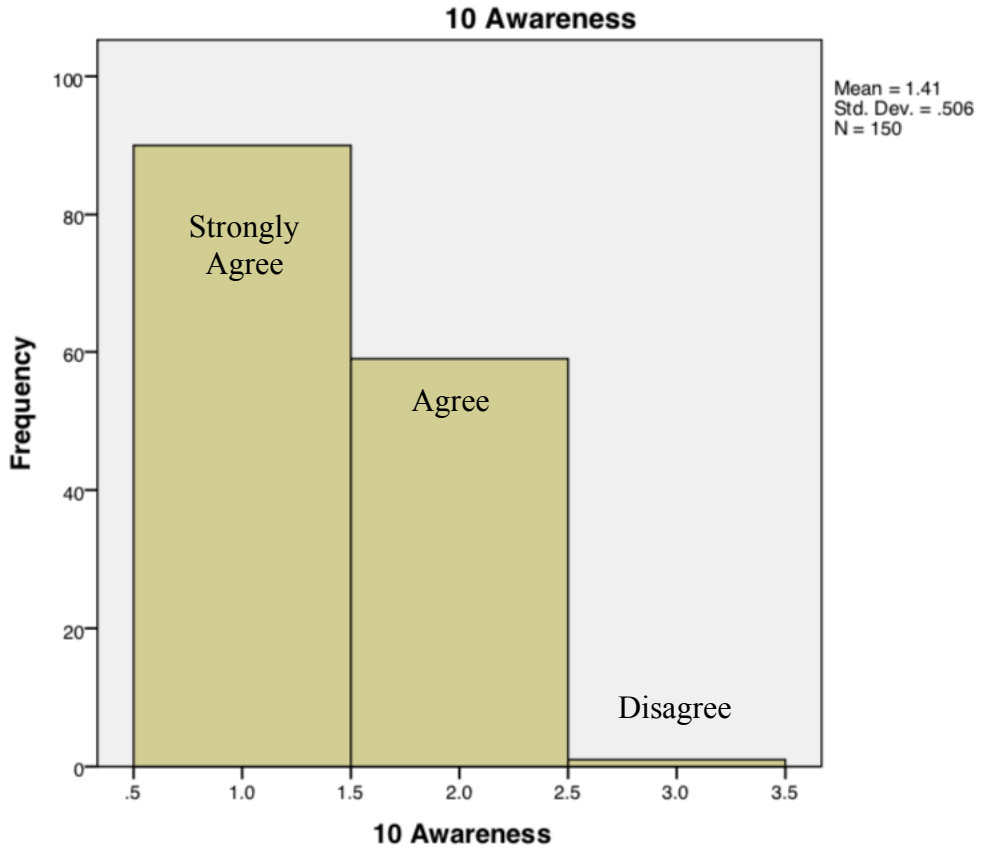

Figure 4- Responses to the statement "I am aware of the risk factors for STF in my workplace".

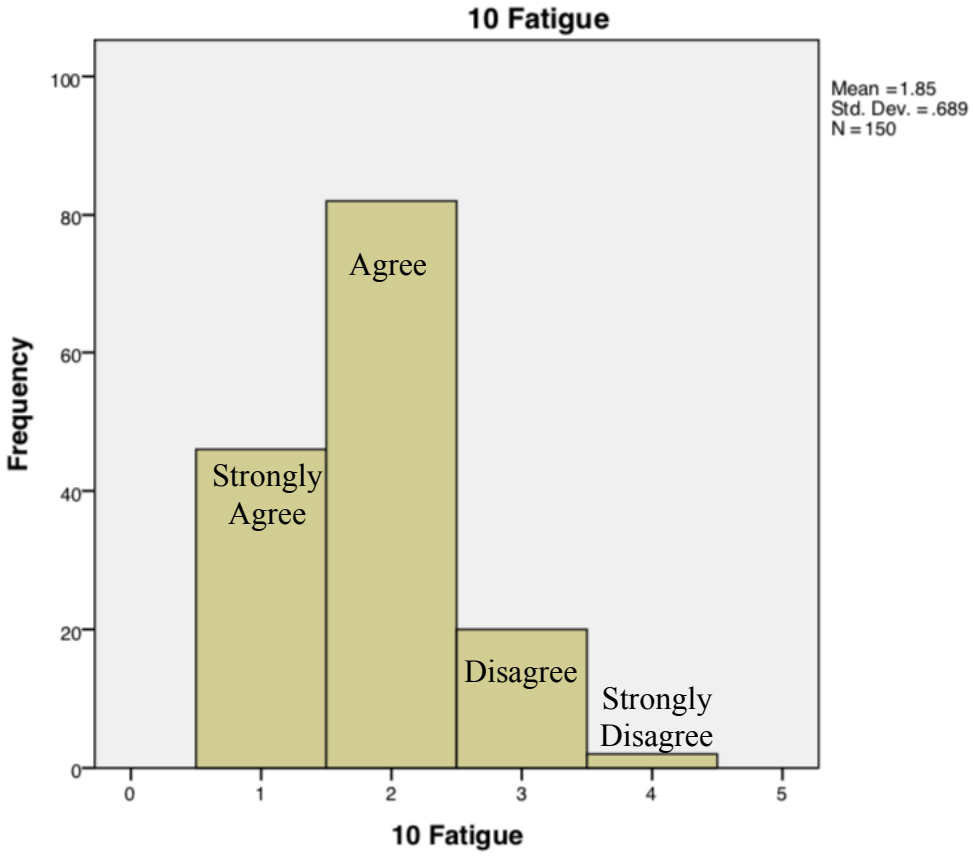

Figure 5- Responses to the statement "My level of fatigue contributes to my risk of STF".

4.7.2 STF Frequency

While majority of the workers reported some type of STF incident within their lifetime only 39.5% and 37.5% of workers reported a STF rarely (once a year) and occasionally (once per month) respectively. Majority of the workers also reported that any of these STF within the last 12 months required no assistance as 59.9-84.1% of workers reported having either a STF or combination incident in this category. A slip with no assistance was the most commonly reported incident with 84.1% of workers indicating that they had had at least one within the last 12 months. A slip with no assistance would be an event where the worker slips but does not sustain

an injury or seek any medical assistance. A trip incident with no assistance was the next most common with 75% of workers reporting at least one incident in this category. There was only one reported combination incident that resulted in a lost time claim within the last 12 months indicating that many of the described incidents from the open-ended question regarding past incidents (question 13- Appendix D) were more than 12 month ago. There were no reported STF incidents requiring a lost time claim when they occurred separately.

Discussion

5 Discussion

The purpose of this study was to determine underground miners' perceptions of STF hazards in Northern Ontario underground hard-rock mines. To the author's knowledge this is the first study to use qualitative and quantitative methods to solicit miners' perceptions of STF hazards in underground hard-rock mining. The top ten risk factors identified by the underground mine workers in the study were uneven terrain, puddles/holes, poor lighting, slippery surfaces, fatigue, getting in/out of equipment, clutter in the walkway, poor vision, walking long distances, and poor balance. This finding is in line with Dobson et al. (2017b) who reported uneven terrain, muscle fatigue and walking long distances risk factors for STFs in coal mines in Australia. The reported top 10 risk factors were grouped into environmental, personal and work task factors. This was confirmed through the qualitative analysis of the open-ended questions which found environmental, equipment and personal factors as the major risk factors for STFs (Tables 3 & 4).

5.1 Environmental Factors

The most frequently discussed risk factors for STFs fell under the environmental theme (Tables 3-5), and included uneven terrain, slippery surfaces, objects in the walkway and water covering the ground. Similarly, the studies by Chang et al. (2016), Bentley et al. (2006) and Dobson et al. (2017b), reported that workers indicated environmental factors as the highest risk factors for STF in underground mines.

Workers identified uneven terrain as the number one risk factor for STF underground (Table 6). Walkway and road conditions underground are rarely predictable and can include

broken rock, potholes, loose ground, and erosion due to changing water levels or changing ground conditions (Ministry of Labour, 2018). Dobson et al. (2017b) also found that uneven terrain was present in underground mines and they went on to indicate uneven terrain affected the normal gait pattern resulting in an increased risk of STFs. In open-ended questions regarding previous STF incidence, workers in this study almost always discussed the unevenness of the terrain as a primary factor for their injury (Table 4).

While uneven terrain was frequently mentioned as a contributing factor for STF risk it was rarely discussed on its own. Workers who indicated uneven terrain as a risk factor almost always discussed this in combination with other factors including puddles/holes, water levels and poor visibility (Tables 3 & 4). The other factors to accompany the description of uneven terrain were also environmental factors such as puddles/holes, water levels and visibility. Workers often described walking and stepping into a puddle that was covering a loose piece of muck or uneven terrain as the conditions around the STF event. This was supported by the ranking of the top 10 STF risk factors as puddles/holes were ranked number two (Table 6). Water is a particular concern as it can erode the ground causing sudden or frequent changes to walk and roadways making conditions unpredictable and it can also create slippery surfaces as it turns to mud (CCOSH, 2018; Dobson et al., 2017b).

Uneven terrain can also be a risk in combination with climbing on/off equipment. Workers who described climbing on/off equipment as a factor for their incident also described uneven terrain or loose chunks as a contributing factor (Table 4). These two factors together may be particularly risky while egressing because to maintain 3-point contact workers cannot see the ground they are stepping onto (proper 3-point contact recommends facing the equipment) and may be more at risk of unknowingly stepping onto uneven terrain below (Work Safe B.C., 2020).

This is also supported by the risks for STFs in mining as reported by Center for Disease Control and Prevention (CDC) (2019) who state that stepping down onto uneven terrain contributes to ingress and egress injuries. However, it was not possible to distinguish one factor from another because workers discussed them in combination so frequently. This finding is in agreement with results of research conducted by Dobson et al. (2017b) who identified multiple factors related to work-boots but could specifically identify work-boots as a risk factor because they could not be isolated from other factors such as terrain. More research is required in this area to identify specific terrain hazards for STF. Furthermore, while uneven terrain is a risk factor for STFs, leading practices in road maintenance can be implemented to mitigate risk. Caterpillar (2020) has reported that best practices for haulage road maintenance in mining include; proper design, operator education, investing in maintenance and clearing debris. These practices could be followed for underground mining roads and walkways to ensure good road conditions.

5.1.1 Clutter in the Walkway

Lipscomb et al. (2006) identified that multiple trades working in close proximity posed a hazard for STFs in the construction industry, due to debris that obstructs the pathways and dust. Findings from this study are in line with Lipscomb and colleagues (2006), as the underground workers identified clutter in the walkway as the 7th of the top 10 risk factors for STFs in their workplace (Table 6). Under the environmental theme was the subtheme of housekeeping and maintenance, in the open-ended questions several workers discussed poor housekeeping in their work area, as a risk factor for STFs. Education about proper housekeeping and hazard awareness, as well as, promotion of protocol compliance could be effective solutions to this risk factor (Bentley et al., 2006).

5.1.2 Housekeeping and Maintenance

While not all environmental factors are able to be controlled, risks related to environmental factors can be mitigated with proper housekeeping and maintenance of road and walkways. According to workers, poor housekeeping and maintenance is a major contributor to causes of uneven terrain, water and clutter in the walkways. This is in agreement with research by Bentley et al. (2006) that stated poorly maintained workspaces were a risk factor for STF in residential construction workers.

The results of question 9 revealed that better maintenance of water and walkways could reduce the severity of uneven terrain. Maintenance of water levels could help to reduce uneven terrain by reducing the amount of corrosion that occurs on roads and walkways. Maintaining water levels could also help to reduce the depth and number of puddles present in working areas. This would improve visibility of the underfoot surfaces allowing workers to better avoid hazards that may have otherwise been hidden by the puddles. More research is required to determine an appropriate maintenance schedule and the best methods for improved maintenance.

Workers also indicated work area housekeeping as a possible solution to improve STF risk. This supports research conducted by (Lipscomb et al., 2006) in the construction industry. The findings in the construction industry indicated that workers may leave tools, equipment and other materials in places that may cause STF risks for other trades working in close proximity. In the mining industry one worker may leave their work materials in the path of another worker causing a STF hazard. This is supported by quantitative data from question 21 where clutter in the walkway was identified as the 7th most risk factor for STF. To reduce clutter and therefore reduce STF risk it is recommended that workers maintain a tidy work area and return equipment

and materials to their designated location. Based on the results of this study STF risk can be reduced by cleaning up the work area and reducing the amount of equipment on the ground.

5.1.3 Lighting

Poor lighting was a descriptor indicated by approximately 80% of workers across both sites, and it was ranked 3rd in the top 10 risk factors for STFs (Table 6). This could also be contributing factor to poor vision which was ranked number 8 in the top 10 factors (Table 6). A dark work environment works in combination with other factors such as uneven terrain, puddles/holes and climbing on/off equipment. A dark environment would make it difficult to see hazards that may be present and for workers to take the appropriate steps to mitigate those hazards (Dobson et al., 2017b).

These results may be an indication that in some instances a single cap lamp may not provide enough lighting for workers to complete daily tasks with minimal risks. Similar to terrain, it was not possible to isolate lighting from other factors. Poor lighting is always present in combination with other environmental factors. It may also be a secondary factor for poor vision next to improper eyewear or dusty conditions. It is not known at this time if more lighting would significantly reduce the risk of STF as it has frequently been overlooked as a risk factor that can be improved in the current literature. Due to the high ranking and frequent discussion by the workers more research is required to confirm that poor lighting is in fact a hazard for STFs, and to find solutions to improve lighting in the underground mining environment.

5.2 Personal Protective Equipment Factors

PPE was identified as a risk factor for STFs in this study (Tables 2-5). Underground coal miners (Dobson et al., 2017b), and firefighters (Kong et al., 2013) have also identified PPE as a risk factor for STFs. The design of the work-boots have been the focus of a large part of the research conducted in mining regarding STF risk (Dobson et al., 2017b). PPE was not ranked in the top 10 ranked risk factors STFs; however, over 50% of the workers indicated that there was something they would change about their PPE. Workers indicated work-boots, shotcrete helmets, and the cap lamp cords specifically as a concern.

Slip on rubber boots were discussed as a risk more frequently than lace-up leather boots. Better boot options and more regular replacement of work-boots were some of the suggestions given by workers. Workers who identified work-boots as a risk factor for STFs also discussed the fit of boots as being poor. This is supported by the results of research conducted by Dobson et al. (2018), who reported fit and weight as reasons for workers' dissatisfaction with their work-boots. Workers also indicated that more regular replacement of work-boots may be a solution to reduce boot-related STF risk. Future research should examine which characteristics of work-boots are leaving workers dissatisfied, determine the impact on gait and investigate improved designs to mitigate risks.

Cap lamps were also reported by 149 workers as a contributing factor to STFs (Table 2). When asked what potential solutions would decrease the risk of STFs, removing the cord on the cap lamps and radios was the most frequent solution discussed, however, workers did not describe why they thought that cap lamp cords contributed to their risk of STFs. Cords on cap lamps run from the lamp placed on the front of the hard hat down to the battery pack on the

miner's belt. Potential reasons for cap lamps contributing to risk of STF could include the cord getting caught on objects and causing a sudden change in gait, movement of the cord into the field of vision and getting in the way when carrying equipment, causing awkward body postures and a change in gait when adjusting a carrying posture. A study conducted by Godwin & Eger (2014) indicated that wireless LED cap lamps are the preferred cap lamp by miners. They also reported that the LED cap lamps provide better lighting for detecting peripheral motion and ground hazards (Godwin & Eger, 2014). This could be beneficial at detecting STF hazards earlier and allow for more time to adjust movements to avoid the hazard. More research is required on cap lamps to determine the exact causes for the cords' contribution to STF risk. Due to the high volume of responses involving cap lamp cords, cordless cap lamps may be a suitable solution to reduce workers risk of STF.

5.3 Work-task Factors

5.3.1 Climbing in/out of equipment

Of all potential work-task factors that were identified in other industries, climbing on/off equipment was the only one that was confirmed by the results of this study. 54.6% of workers strongly agreed climbing on/off equipment was a risk factor for STF and ranked it 6th in the results of the top 10 risk factors (Table 6). The analysis of the open-ended questions also supported these results as it was discussed 34 times when describing the factors contributing to a previous STF incident (Table 4).

While climbing on/off of equipment was identified as one of the top 10 risk factors it was often discussed in combination with another factor. It was most frequently discussed

alongside environmental factors such as uneven terrain or puddles. It was also discussed alongside some personal factors such as balance, awareness and fatigue. Ingressing/egressing from equipment was often the secondary factor when describing a previous STF incident. This is a strong indication that these factors work in combination with one another.

Jumping from equipment was not identified by any of the workers which is in disagreement with information from Canadian Center for Occupational Health and Safety (2018). Climbing ladders or stairs separate from equipment was also not identified as a risk factor by any of the workers as suggested by results of research in the construction industry (Bentley et al., 2006). This could be because ladders and stairs separate from equipment may not be used as commonly to complete daily tasks underground as compared to other industries such as, the construction industry.

5.3.2 Planning and Organization of Work

Planning and organization of work was not identified as a main cause for STF incidents. However, workers did discuss these factors as potential solutions for preventing future STF incidents. Under the subtheme of housekeeping and maintenance workers discussed better planning of equipment and walkway maintenance. This is supported by research from New Zealand in the construction industry that found planning and organization of work had an effect on worker behaviour (Bentley et al., 2006).

It was suggested that more regular equipment maintenance could help to keep equipment, specifically areas of climbing on/off, in good condition. When describing a previous STF incident workers described a step breaking or railing falling off as contributing factors to their fall. Similarly, workers suggested that planning for more regular road and walkway maintenance

could improve the severity of uneven terrain and water related factors. While factors like uneven terrain and puddles cannot be eliminated from underground mining, managing their severity could help to significantly reduce the number of STF incidents. Future research is required to determine more specific programs to improve planning and organization of work.

5.4 Personal Factors

The unpredictable conditions of the mine requires workers to be constantly aware of potential hazards (Bentley et al., 2006). This statement supports workers indication of awareness as a potential hazard for STF. Awareness was discussed throughout the open-ended questions. Some workers identified lack of awareness as a contributing risk factor to a STF incident. While 59.3% indicated they are strongly aware of the risk factors, the discussion of various personal factors is an indication that steps could be taken to reduce the risk of STF due to personal factors. Personal factors was the 3rd major theme emerge from the thematic analysis of risk factors from previous incidents and current risk factors reported by workers (Tables 3 & 4). However, while describing a previous incident, workers who discussed personal factors did not attribute them as the main cause of the incident. This is a strong indication that personal factors are likely a hazard when combined with another risk factor.

5.4.1 Attention, Fatigue and Balance

Fatigue was the most frequently discussed and most highly ranked of all the personal factors. With a rank of 5 out of 10, the majority of workers agreeing with it being a hazard it is clear that fatigue is a major contributor to one's risk of STF. This is supported by research by Dobson and colleagues (2017b) who suggested that it may contribute to workers' ability to

observe a hazard in the first place. The workers did not expand on why or how fatigue may be a risk factor for STF. Some studies suggest that worker fatigue could be due to work environment, laborious tasks, stress, and poor sleep quality or quantity (Butlewski et al., 2015; McGillis et al., 2017). Shift work has been shown to increase levels of fatigue and workload during a shift can contribute as well (Dobson et al., 2015) and has also indicated that the weight of the work-boots may decrease time to muscle fatigue contributing to a worker's overall level of fatigue. Homelife and lifestyle may also play a role in the level of fatigue experienced by individual workers as Butlewski et al. (2015) reports that healthy lifestyle and nutrition is a way to mitigate fatigue.

Fatigue can also impair a worker's attention when performing a task (McGillis et al., 2017). Workers in this study also reported rushing to complete a task as a reason for decreased attention while at work. Rushing was a category within the sub theme of attention for previous incidents and for current risk factors, as well as, overall risk factors. A worker's attention may also be limited by a lack of environmental and visual stimulus due to the lack of lighting reported. Bentley et al. (2006) also suggests that divided attention may also be a factor. While divided attention was not specifically mentioned by workers it may still be a contributing factor. More research is required to determine the impact of fatigue on STFs in underground mining.

Poor balance was reported as 10th risk factor (Table 6). It was also discussed frequently in combination with uneven terrain and climbing on/off equipment; however, it was not discussed on its' own suggesting that it is likely a secondary factor. Balance may also be affected by a worker's level of fatigue as suggested by Dobson et al. (2017b). If workers are feeling more fatigued, they may be more likely to have difficulty balancing. However, this is also a secondary factor to others that may contribute more completely to an incident. More research is required to isolate these variables and determine how they interact with one another.

5.4.2 Demographics, Experience and Position

Research conducted in the firefighting industry indicated that BMI could play a role in STF risk at the beginning of a worker's career because of decreased muscle strength and weight distribution (Kong et al., 2013). In the results of this study there was no correlation between height and or weight and reported STF frequency. While physical fitness may still be a contributing factor to STF it is likely to be secondary to other more prominent risk factors. The More research is required to determine to which extent physical fitness is involved in STF risk.

Some research has suggested that age may play a role in a workers risk for STF incidents (Kemmlert & Lundholm, 2001). Previously it was found that being 45 years or older took longer leave due to an incident (Kemmlert & Lundholm, 2001). The results of this research found that age was not a predictor for or correlated to STF frequency. Similarly, experience has been shown to be risk factor where the more experience a worker has the more aware they are of the hazards (Kemmlert & Lundholm, 2001). This was not supported by the results of this study as there was no relationship between experience and STF frequency.

There was also no relationship between a worker's position and STF frequency. This may be due to the larger number of categories for working positions and a small number of workers in this study. It is possible that a larger sample size or research with a focus on less work positions may find evidence that contradicts these findings. While there was no relationship found in this study between age, gender, height, weight, position or experience and risk of STFs this study had a limited number of participants, therefore, these factors may still contribute to STFs risk.

5.4.3 Vision

Poor vision was ranked 8th in the top 10 risk factors; however, it was rarely discussed throughout the entirety of the open-ended responses. This may be due to variety of factors that ultimately results in poor vision leading workers to indicate poor vision as a risk factor itself. Examples of this would be dusty and/or poorly lit conditions resulting in a lack of visual stimulus and leading to an increased risk of STF. This is supported by findings in the construction industry (Bentley et al., 2006). A worker's prescription or lack thereof, as well as, dirty or scratched protective eyewear may cause a decrease in the quality of their vision (Saskatchewan Health Authority, 2017). This would make it difficult to observe the hazards that are present in the work area.

It is unclear why poor vision has been indicated as a risk factor for STF in the present study. Almost all of the workers who identified their position as a shotcreter indicated that the shotcrete helmet was a risk factor for STF (Appendix F). The workers who indicated the helmet as a problem described it as impeding their vision or diminishing the quality of their vision. Despite not reaching saturation based on the responses given by shotcreters it can be assumed that the helmets cause poor visibility which could lead to an increased risk of STFs. More research on this particular piece of equipment may be beneficial in the future.

5.4.4 Hydration

46.3% of workers agreed that hydration was a risk factor for STF. Dehydration could be a result of long work hours in a hot environment. As previously mentioned, heat was frequently discussed alongside fatigue (Tables 3-5). Excess exposure to heat could lead to dehydration

which could cause feelings of fatigue (Konrad et al., 2019). Hydration and fatigue could also have an effect on a person's attention. When prompted, workers indicated that hydration may contribute to STF; however, it was only discussed once throughout all of the open-ended responses (Table 3). Therefore, it is likely a contributor for other factors as opposed to a direct risk for STF. For example, walking long distances was also ranked 9th in the top 10 risk factors (Table 6) but was rarely mentioned during other responses. Walking long distances in the heat could lead to dehydration which then leads to decreased attention and fatigue. Walking long distances, heat and dehydration may not be risk factors on their own but together they may lead to increased fatigue which then affects a worker's risk of a STF incident.

Workers suggested having more available transportation to reduce the amount of walking may be beneficial at reducing STF risk (Table 5). One worker suggested that having more electrolyte replenishing beverages may assist in the prevention of dehydration, however, this has yet to be researched in an underground mining environment.

"Supply more gator aid drinks" (P#56)

Appropriate steps to prevent heat stroke such as; taking breaks, drinking cold or room temperature liquids, and wearing sweat wicking layers may be beneficial to mitigating the effects of heat (CCOHS, 2016).

5.5 Limitations

The first limitation of this study is the reliance on participants to recall previous experiences related to STFs. One of the questions required participants to recall STF incidents through the lifetime of their career while others required participants to recall STF specifics from

the last 12 months. Workers may also notice some factors more than others. This does not always correspond to risk. Due to these limitations, details regarding the cause of STF incidents may be less specific or not described and the number of reported STF incidents may be lower because they simply do not remember each and every incident that they have experienced. However, participants are likely to remember an incident that resulted in an injury or a claim. To better collect information while it is more easily recalled researchers could have workers complete a form immediately following a STF incident or track STF incidents as they happen to capture a more accurate number. This may be difficult due to the nature of the work but would improve the quality of worker recall. Moreover, it is likely that this study has captured the factors related to the most severe STF incidents experienced by workers. This remains a strong indication of the factors that contribute to STF in mining in general.

The second limitation of this study is that it evaluates a person's workplace and it was completed on work time. While completing the survey on paid time may have increased the number of participants, workers may have been hesitant to report an incident in fear of repercussions to their job or having a supervisor see their responses, despite being informed by the research team that their responses would only be viewed by the research team. Workers may be less likely to report an incident that they did not report to their workplace regardless of the anonymity of the survey. Some workers indicated that they would not give details of their STF incident for this reason. To protect the best interest of the participants falls from a height and same level falls were combined. This was done to prevent participants from being identified through the reporting of their quotations. This could be improved in future research by conducting data collection outside of the workplace or by having the room free of supervisors and management.

Another limitation of this study was the amount of options provided for some of the questions. For example, due to the high variety of skills required for mining there were a high number of different working positions which resulted in a low power when assessing a relationship between STFs risk and working position. Ultimately this resulted in an insignificant relationship as mentioned in Chapter 4. This could be resolved by obtaining a higher number of participants or only looking at a specific number of working positions.

Lastly, there may be some bias in the reporting of cap lamp cords as a factor due to the order of the questions. Workers were asked if their cap lamp contained a cord before being asked which pieces of PPE they believed contributed to their risk of STF. Almost 100% of workers reported that their cap lamp had a cord while only 50% of workers said they would change something about their PPE. Meaning that less than 50% indicated that they would change their cap lamp. This could be avoided in the future by asking the questions in a different order.

5.6 Future Research

There remains little research in the mining industry regarding STFs. This study was able to identify general risk factors for STFs as reported by workers. However, it was not able to isolate specific factors or hazards. All factors seem to work in combination with each other. Therefore, research that aims to determine the extent to which each factor contributes to a worker's risk could improve the understanding of why STFs continue to be a problem.

Specifically, future research should focus on the high-risk areas identified in this study. Environmental factors are difficult to mitigate in a mine setting; however, more research is required to determine how to reduce severity of uneven terrain, improve lighting and visibility

and manage water to reduce the severity of puddles. Research that focuses on equipment design for underground mining equipment could help to improve body mechanics required to ingress and egress from equipment. Moreover, based on workers' responses, investigation into maintenance programs for equipment and environmental factors (ex. Road and walkway conditions) would be beneficial to the industry. Furthermore, a survey design that allows for analysis of a relationship between STF risk and working role/position would be beneficial to understand how different roles are affected.

Future research should also aim to investigate PPE overall in relation to STFs as previous research has focused on work-boots specifically. More specifically, workers have identified cap lamp cords and shotcrete helmets as hazards. To my knowledge, both of these have yet to be assessed in the literature. Research investigating the reason why workers identified certain pieces of PPE would be beneficial as workers gave little description beyond simply identifying the PPE.

Lastly, research in the area of personal factors should focus on determining if these factors are secondary to a more primary factor. Factors such as attention and fatigue were identified but research in this area is limited in the mining industry.

5.7 Conclusion

This study aimed to identify underground miners' perceptions of STFs hazards in Northern Ontario underground hard-rock mines. Workers participated by answering open and closed-ended questions on an anonymous survey. Environmental factors were discussed most frequently. Five of the top 10 risk factors for STF were environmental factors. These included uneven terrain, puddles/holes, poor lighting, slippery surfaces and clutter in the walkway. Work-

task factors were also identified with the most common hazard being climbing on/off equipment. Workers suggested that better maintenance and housekeeping programs could help to reduce environmental and work-task factors hazards.

PPE and personal factors were also identified. Fatigue, poor vision and poor balance were identified in the top 10 risk factors for STF. The thematic analysis of previous injury responses and hazards in general also revealed PPE and personal factors as hazards. However, these factors were mostly discussed in combination with other hazards. Research on better housekeeping and maintenance programs, the extent to which environmental, work-task, PPE and personal factors contribute to STF risk is still required. More research in this industry would be beneficial to investigate all of these factors and continue to improve safety in mining.

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Appendices

See below for all appendices referenced in this document

Appendix A

Laurentian Research Ethics Board Certificate of Ethics Approval

APPROVAL FOR CONDUCTING RESEARCH INVOLVING HUMAN SUBJECTS
Research Ethics Board – Laurentian University

This letter confirms that the research project identified below has successfully passed the ethics review by the Laurentian University Research Ethics Board (REB). Your ethics approval date, other milestone dates, and any special conditions for your project are indicated below.

TYPE OF APPROVAL / New X / Modifications to project / Time extension	
Name of Principal Investigator and school/department	Chelsea Sherrington, Human Kinetics, supervisors, Alison Godwin, Tammy Eger
Title of Project	Slips Trips and Falls in Northern Ontario Underground Mines
REB file number	6018365
Date of original approval of project	02 August, 2019
Date of approval of project modifications or extension *(if applicable)*	
Final/Interim report due on: *(You may request an extension)*	02 August, 2020
Conditions placed on project	

During the course of your research, no deviations from, or changes to, the protocol, recruitment or consent forms may be initiated without prior written approval from the REB. If you wish to modify your research project, please refer to the Research Ethics website to complete the appropriate REB form.
All projects must submit a report to REB at least once per year. If involvement with human participants continues for longer than one year (e.g. you have not completed the objectives of the study and have not yet terminated contact with the participants, except for feedback of final results to participants), you must request an extension using the appropriate LU REB form. In all cases, please ensure that your research complies with Tri-Council Policy Statement (TCPS). Also please quote your REB file number on all future correspondence with the REB office.
Congratulations and best wishes in conducting your research.

Rosanna Langer

Rosanna Langer, PHD, Chair, *Laurentian University Research Ethics Board*

Appendix B

English Participant Consent Form.

INFORMED CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Title: Slips, Trips and Falls in Northern Ontario Underground Mines

Principal Investigators: Chelsea Sherrington & Tammy Eger

Contact Information: Phone: 705-675-1151 Email: csherrington@laurentian.ca
teger@laurentian.ca

Sponsor: Center for Research in Occupational Safety and Health (CROSH)

INFORMED CONSENT
You are being asked to consider participating in a research study. A research study is a way of gathering information on a treatment, procedure or program or to answer a question about something that is not well understood. This form explains the purpose of this research study, provides information about the study procedures, possible risks and benefits, and the rights of participants.

Please read this form carefully and ask any questions you may have. The researcher will explain this form and all information concerning the study to you verbally. Please ask the researcher to clarify anything you do not understand or would like to know more about. Make sure all your questions are answered to your satisfaction before deciding whether to participate in this research study.

Participating in this study is your choice (voluntary). You have the right to choose not to participate, and you have the right to withdraw from the study and stop your participation at any time. If you decide to stop participating, your data will be removed and there will be no consequences to you or the services you receive.

INTRODUCTION
You are being asked to consider participating in this study because you are a worker in a northern Ontario underground hard-rock mine. As such, you have the knowledge required to help guide the research being done in the mining industry in regard to slips trips and falls.

WHY IS THIS STUDY BEING DONE?
This study is being done to determine the main risk factors for slips, trips and falls in northern Ontario underground hard-rock mines. By identifying the potential risk factors more focused research can be carried out to better understand why slips, trips and falls occur in underground mines and how to prevent them. It could also help companies and manufactures in the mining industry design better products and training programs to prevent slips, trips and falls in the future.

WHAT WILL HAPPEN DURING THIS STUDY?
You will be asked to complete a survey with 22 questions about your work experience, work environment, work attire, history with slips, trips and falls, and a few questions on your age, height etc. The survey should take approximately 20 minutes to complete. Following the survey, you are welcome to stay for a brief presentation on slips, trips, and falls in the workplace.

WHAT ARE THE RISKS OR HARMS OF PARTICIPATING IN THIS STUDY?
There are no medical risks to you from participating in this study, but it is possible that a question we ask may be stressful for you or make you uncomfortable. You may decline to answer the question or stop the survey at any time if you experience any discomfort. You do not need to answer questions that make you uncomfortable or that you do not want to answer.

Your job will not be affected in any way by participating in this study. All information obtained in this study will remain confidential and will not be used to by your employer to alter your job status in any way. Participation in this study is voluntary. Choosing to participate, not participate or withdraw from the study will not have any repercussions on your job. If you have any concerns, contact Chelsea Sherrington.

WHAT ARE THE POTENTIAL BENEFITS?
Individual Benefits - You may or may not benefit directly from participating in this study.

Benefits to the Scientific/Academic Community – You will help guide the focus areas of future research in the mining industry in regard to slips, trips and falls. This could help initiate research for potential prevention solutions.

ARE STUDY PARTICIPANTS PAID TO PARTICIPATE IN THIS STUDY?
You will not be paid for participation in this study, it is voluntary.

HOW WILL MY INFORMATION BE KEPT CONFIDENTIAL?
All information that is collected, used or disclosed for this study will be handled in a confidential manner. Anything that you say or do in the study will not be attributed to you personally. Anything that we find out about you that could identify you will not be published or told to anyone else, unless we get your permission. Reports based on the gathered data will contain no information that might link an individual with a particular statement, unless expressed permission has been granted. The information obtained will be kept electronically on Laurentian University's secure Google Drive system for research data storage and be only available to the research team at the Centre for Research on Occupational Safety and Health. Paper surveys will be secured for 7 years then destroyed.

INFORMATION ABOUT THE STUDY RESULTS
You have the right to be informed of the results of this study once the study is complete. If you would like to be informed of the results of this study, please contact Chelsea

Sherrington at csherrington@laurentian.ca or provide your e-mail address at the end of this form.

If you would like to receive the results of this study directly please provide your e-mail address below. This will not be used to as means to identify you in any way in the study. You will not receive any other e-mails from Laurentian University or the Centre for Research in Occupational Safety and Health (CROSH) by providing your e-mail address below. If you do not wish to provide an e-mail contact but still wish to know the results of the study, they will be accessible through Laurentian University's Centre for Research in Occupational Safety and Health at the conclusion of the study.

_____

e-mail address

WHAT ARE THE RIGHTS OF PARTICIPANTS IN A RESEARCH STUDY?
You have the right to receive all information that could help you make a decision about participating in this study. You also have the right to ask questions about this study and your rights as a research participant, and to have them answered to your satisfaction, before you make any decision. You also have the right to ask questions and to receive answers throughout this study. If you have any questions about this study, you may contact the person in charge of this study (Chelsea Sherrington) at csherrington@laurentian.ca or at Center for Research in Occupational Safety and Health at 705-675-1151 ext 1422.

If you have questions about your rights as a research participant or any ethical issues related to this study that you wish to discuss with someone not directly involved with the study, you may call **Research Ethics Officer, Laurentian University Research Office,** telephone: 705-675-1151 ext 3681, 2436 or toll free at 1-800-461-4030 or email ethics@laurentian.ca.

DOCUMENTATION OF INFORMED CONSENT

You will be given a copy of this informed consent form after it has been signed and dated by you and the study staff.

Full Study Title: Slips, Trips and Falls in Northern Ontario Underground Mines.

Name of Participant: _____

Participant/Substitute decision-maker
By signing this form, I confirm that:
- This research study has been fully explained to me and all of my questions answered to my satisfaction
- I understand the requirements of participating in this research study
- I have been informed of the risks and benefits, if any, of participating in this research study
- I have been informed of any alternatives to participating in this research study
- I have been informed of the rights of research participants
- I have read each page of this form
- I agree to participate in this research study

_____	_____	_____
Name of participant/ (print)	Signature	Date
_____	_____	_____
Name of Person administering	Signature	Date

Appendix C

French Participant Consent Form

CONSENTEMENT ÉCLAIRÉ À PARTICIPER À UNE ÉTUDE

Titre : Dérapages, pertes d'équilibre et chutes dans les mines souterraines du Nord de l'Ontario

Chercheuses principales : Chelsea Sherrington et Tammy Eger

Téléphone : 705-675-1151 Courriel : csherrington@laurentian.ca
teger@laurentian.ca

Commanditaire : Centre de recherche en santé et sécurité au travail (CRSST)

CONSENTEMENT ÉCLAIRÉ
Nous vous demandons d'envisager de participer à une étude. Une étude est un moyen de recueillir des renseignements sur un traitement, un processus ou un programme ou de répondre à une question sur quelque chose qui n'est pas bien compris. Ce formulaire explique l'objet de l'étude, fournit des renseignements sur le processus, les risques et avantages possibles de l'étude, et les droits des participants.

Veuillez lire ce formulaire soigneusement et poser vos questions éventuelles. La chercheuse vous expliquera de vive voix ce formulaire et tous les renseignements concernant l'étude. Demandez-lui de clarifier tout point que nous ne comprenez pas ou sur lequel vous aimeriez en savoir davantage. Vérifiez que vous avez obtenu une réponse satisfaisante à toutes vos questions avant de prendre une décision sur la participation à cette étude.

Vous êtes tout à fait libre de participer à cette étude (participation volontaire). Vous avez le droit de choisir de ne pas y participer ainsi que celui de vous retirer en tout temps. Si vous décidez de vous retirer, vos données seront supprimées et il n'y aura aucune conséquence pour vous ou sur les services que vous recevez.

INTRODUCTION
Vous êtes invité(e) à participer à cette étude parce que vous travaillez dans une exploitation minière souterraine en roche dure dans le Nord de l'Ontario et possédez par conséquent les connaissances requises pour aider à guider les recherches menées dans l'industrie minière concernant les dérapages, les pertes d'équilibre et les chutes.

POURQUOI CETTE ÉTUDE EST EFFECTUÉE
Cette étude est effectuée afin de déterminer les principaux facteurs de risque de dérapage, de perte d'équilibre et de chute dans les mines souterraines du Nord de l'Ontario. En recensant les facteurs de risque potentiels, il est possible de bien cibler les recherches pour bien comprendre pourquoi les dérapages, les pertes d'équilibre et les chutes surviennent dans les mines souterraines et comment les prévenir. L'étude

pourrait aussi aider les entreprises et manufactures du secteur minier à concevoir de meilleurs produits et programmes de formation pour prévenir ces incidents à l'avenir.

DÉROULEMENT DE L'ÉTUDE
Vous devrez participer à un sondage comportant 22 questions sur votre expérience de travail, votre environnement de travail, votre tenue de travail, vos antécédents de dérapage, de perte d'équilibre et de chute, ainsi que sur votre âge, votre taille, etc. Il faudra environ 20 minutes pour répondre au questionnaire. Ensuite, vous pourrez rester pour assister à une courte présentation sur les dérapages, les pertes d'équilibre et les chutes sur le lieu de travail.

RISQUES OU DÉSAVANTAGES DE LA PARTICIPATION À CETTE ÉTUDE
La participation à cette étude ne comporte aucun risque pour la santé mais il est possible qu'une question puisse être stressante ou vous dérange. Vous pouvez refuser de répondre à cette question ou arrêter de répondre au sondage si vous êtes mal à l'aise.

La participation à cette étude n'aura aucune conséquence sur votre emploi. Tous les renseignements obtenus demeureront confidentiels, et votre employeur ne les utilisera pas pour modifier le statut de votre emploi. La participation à cette étude est volontaire. Le fait d'accepter ou de refuser d'y participer ou de vous retirer n'aura aucune répercussion sur votre emploi. Si vous avez des préoccupations, communiquez avec Chelsea Sherrington.

AVANTAGES POTENTIELS
Avantages individuels – Vous ne bénéficierez pas nécessairement directement de la participation à cette étude.

Avantages pour la communauté scientifique/universitaire – Vous aiderez à déterminer l'accent de futures études dans le secteur minier en ce qui concerne les dérapages, les pertes d'équilibre et les chutes. Cela pourrait aider à lancer des études pour trouver des moyens potentiels de prévention.

RÉMUNÉRATION DES PARTICIPANTS
Vous ne serez pas rémunéré(e) pour participer à cette étude. La participation est volontaire.

CONFIDENTIALITÉ DES RENSEIGNEMENTS
Tous les renseignements provenant de cette étude recueillis, utilisés ou divulgués seront traités confidentiellement. Tout ce que vous dites ou faites pendant l'étude ne vous sera pas attribué personnellement. Tout renseignement qui pourrait permettre de vous identifier ne sera ni publié ni divulgué à qui que ce soit sans votre permission. Les rapports fondés sur les données recueillies ne contiendront aucun renseignement qui pourrait permettre de faire le lien avec la déclaration d'une personne à moins d'avoir sa permission expresse. Les renseignements recueillis seront conservés sur un support électronique dans le système Google Drive sécurisé de l'Université Laurentienne qui

réservé pour entreposer les données de recherche, et seule l'équipe de recherche du Centre de recherche sur la santé et la sécurité au travail y aura accès. Les sondages imprimés seront conservés en sécurité pendant sept ans puis seront détruits.

RENSEIGNEMENTS SUR LES RÉSULTATS DE L'ÉTUDE
Vous avez le droit d'obtenir les résultats de l'étude lorsqu'elle sera terminée. Si vous désirez les obtenir, écrivez à Chelsea Sherrington at csherrington@laurentian.ca ou fournissez votre adresse électronique à la fin de ce formulaire.

Si vous désirez recevoir les résultats de l'étude directement, veuillez indiquer votre adresse électronique ci-dessous. Elle ne servira pas à vous identifier de quelque manière que ce soit dans l'étude. Vous ne recevrez aucun autre message électronique de l'Université Laurentienne ou du Centre de recherche sur la santé et la sécurité au travail. Si vous ne voulez pas fournir votre adresse électronique mais souhaitez quand même connaître les résultats de l'étude, vous pourrez les obtenir au Centre de recherche sur la santé et la sécurité au travail de l'Université Laurentienne à la fin de l'étude.

_____
Adresse électronique

DROITS DES PARTICIPANTS À UNE ÉTUDE
Vous avez le droit de recevoir tous les renseignements qui pourraient vous aider à prendre une décision sur la participation à cette étude. Vous avez aussi le droit de poser des questions sur l'étude et sur vos droits en tant que participant(e) et d'obtenir une réponse satisfaisante avant de prendre toute décision. Si vous avez des questions, vous pouvez vous adresser à la responsable de l'étude, Chelsea Sherrington, à csherrington@laurentian.ca ou au Centre de recherche sur la santé et la sécurité au travail au 705-675-1151, poste 1422.

Si vous avez des questions sur vos droits en tant que participant(e) à l'étude ou sur tout aspect éthique de cette étude dont vous voulez discuter avec une personne qui n'est pas directement engagée dans l'étude, vous pouvez appeler **l'agente responsable de l'éthique des recherches, Bureau de recherche de l'Université Laurentienne,** téléphone : 705-675-1151, poste 3681 ou 2436 ou appeler sans frais au 1-800-461-4030 ou écrire à ethics@laurentian.ca.

DOCUMENTATION DU CONSENTEMENT ÉCLAIRÉ

Vous recevrez une copie de ce formulaire de consentement éclairé lorsque vous et le membre du personnel responsable de l'étude l'aurez signé.

Titre complet de l'étude : Dérapages, pertes d'équilibre et chutes dans les mines souterraines du Nord de l'Ontario

Nom du(de la) participant(e) : _____

Participant(e)/mandataire
En signant ce formulaire, je confirme ce qui suit :
- On m'a pleinement expliqué cette étude et j'ai obtenu une réponse satisfaisante à toutes mes questions.
- Je comprends les exigences de la participation à cette étude.
- On m'a indiqué les risques et les avantages éventuels de la participation à cette étude.
- On m'a indiqué les solutions de rechange à la participation à cette étude.
- On m'a indiqué les droits des participants à une étude.
- J'ai lu chaque page de ce formulaire.
- J'accepte de participer à cette étude.

_____	_____	_____
Nom du(de la) participant(e)/ (lettres moulées)	Signature	Date

_____	_____	_____
Nom de la personne qui	Signature	Date

Appendix D

English Survey Package

Slips Trip and Falls in Underground Hard-Rock Mines

Participant Survey Package

Fall 2019

Thank you for completing the consent form to participate in this study on Slips, Trips, and Falls in Underground Mining.

Please answer the questions that follow. All responses are confidential. No personal information will be shared. If you wish to withdraw from the study you can do so at any time without penalty.

1. How old are you?
    a. 18 – 25 years
    b. 26 – 35 years
    c. 36 – 45 years
    d. 46 – 55 years
    e. 56 – 65 years
    f. Over 65 years

2. What is your sex?
    a. Male
    b. Female
    c. Other: _____
    d. Prefer not to disclose

3. What is your height? _____

4. What is your weight? _____

5. What is your current working position/role at this mine?
    a. Driller
    b. Operator
    c. Electrician
    d. Mechanic
    e. Supervisor/ Crew Leader
    f. Support Miner
    g. Other: _____

6. How many years have you worked underground in a hard rock mine?
    a. Less than 1 year
    b. 1 – 5 years
    c. 6 – 10 years
    d. 11 – 20 years
    e. 21 – 30 years
    f. 30+ years

7. Please describe the **main tasks** of your current working position.

8. Circle **ALL** the words that best describe your work environment:
    a. Poor lighting/dark
    b. Well lit
    c. Hot
    d. Cold
    e. Wet
    f. Dry
    g. Slippery
    h. Even terrain
    i. Smooth terrain
    j. Uneven terrain
    k. Loose terrain
    l. Other words (please list):

9. What factors do you think contribute to your risk of slips, trips or falls? Please describe below:

10. Please indicate how much you agree with the statements below.

	Strongly Agree	**Agree**	**Disagree**	**Strongly Disagree**
The **work environment** contributes to my risk of slips, trips and falls				
My level of **fatigue** contributes to my risk of slips, trips and falls				
My level of **hydration** contributes to my risk of slips, trips and falls				
Climbing on/off equipment contributes to my risk of slips, trips and falls.				
I **am aware of the risk factors** for slips, trips and falls in my workplace				

11. Please complete the following sentence. I am more likely to slip, trip or fall _____. Circle **ALL** that apply

    a. At the beginning of my shift
    b. Before lunch
    c. After lunch
    d. Towards the end of my shift

12. How often do you walk during your shift?
    a. Hardly at all (less than 7 min)
    b. Rarely (7min – 36min)
    c. Occasionally (37min – 3hrs 59min)
    d. Frequently (4hrs – 7hrs 59min)
    e. Continuously (8hrs – 12hrs)

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13. In your lifetime what is the worst slip trip and/or fall event you have experienced while working in an underground mine? Please describe the conditions and/or events that resulted in the slip, trip and/or fall. If you have never had a slip, trip, or fall please move to the next question.

14. How often do you notice that you slip, trip, or fall at work?
    a. Never
    b. Rarely (1 per year)
    c. Occasionally (1 per month)
    d. Frequently (1 per week)
    e. Quite Often (more than 2 times per week)

15. **Think about slips, trips or falls at work that you have experienced in the past 12 months** and **check ALL the boxes in the table that apply**:

	No assistance. (no injury sustained)	**First Aid (mild injury)**	**Medical Aid**	**Lost-Time Claim**
I had a **slip** that required:				
I had a **trip** that required:				
I had a **fall** that required:				
I had a **combination of at slip, trip and fall** that required:				

16. Which work boots do you wear? Please provide the manufacturer (make/model) if known.

Leather Style Lace-up Boot

Make/Model: _____

Rubber-Mucker Style Boot

Make/Model: _____

17. Does your cap lamp have an attached cord?
    a. Yes
    b. No

18. Do you think any of your personal protective equipment contributes to your risk of slips, trips and falls? Circle **ALL** that apply:
    a. Coveralls
    b. High visibility pants and shirt
    c. Lace up leather work boots
    d. Slip on rubber work boots
    e. Half face respirator
    f. Miner's belt
    g. Protective eye wear
    h. Hard hat
    i. Work gloves
    j. Cap lamp
    k. Other: Please Specify _____

19. Is there anything you would change about your current personal protective equipment? If yes, please specify.
    a. No
    b. Yes.

20. What would you recommend to reduce the risks of slips, trips and falls at work?

21. Which of the following factors contribute most to your risk of slips, trips, and falls at work? Please rank **10** factors in order where 1 contributes to **most** and 10 contributes the **least**.

uneven terrain		cap lamps	
work boot weight		poor vision	
poor lighting		protective safety glasses	
high-visibility clothing		hydration level	
fatigue		previous injuries	
walking long distances		poor grips on the work-boots	
poor balance		clutter in walkways	
puddles/holes		slippery surfaces	
awareness		distraction	
poor work boot fit		getting in/out of equipment	
Other (describe):		Other (describe):	

22. Is there anything else you would like to share about your experiences with slips, trips and falls at work and/or recommendations to prevent slips, trips, and falls at work?

Thank you for taking the time to complete this confidential survey on slips, trips and falls in underground mining.

Appendix E

French Survey Package

Dérapages, perte d'équilibre et chutes dans les mines souterraines du Nord de l'Ontario

Trousse de sondage du(de la) participant(e)

Automne 2019

Merci d'avoir rempli le formulaire de consentement à la participation à cette étude sur les dérapages, pertes d'équilibre et chutes dans les mines souterraines du Nord de l'Ontario

Veuillez répondre aux questions qui suivent. Toutes les réponses demeureront confidentielles et aucun renseignement personnel ne sera divulgué. Si vous désirez vous retirer de l'étude, vous pouvez le faire en tout temps sans vous exposer à des pénalités.

1. Quel âge avez-vous?
    a. 18 – 25 ans
    b. 26 – 35 ans
    c. 36 – 45 ans
    d. 46 – 55 ans
    e. 56 – 65 ans
    f. Plus de 65 ans

2. Quel est votre sexe?
    a. Masculin
    b. Féminin
    c. Autre : _____
    d. Je préfère ne pas le dire

3. Combien mesurez-vous? _____

4. Combien pesez-vous? _____

5. Quel est votre poste/rôle actuel dans cette mine?
    a. Foreur/foreuse
    b. Opérateur/opératrice
    c. Électricien/électricienne
    d. Mécanicien/mécanicienne
    e. Superviseur/chef d'équipe
    f. Mineur/mineuse de soutien
    g. Autre : _____

6. Depuis combien de temps travaillez-vous dans une mine en roche dure?
    a. Moins d'un an
    b. 1 – 5 ans
    c. 6 – 10 ans
    d. 11 – 20 ans
    e. 21 – 30 ans
    f. Plus de 30 ans

7. Décrivez les **principales tâches** de votre poste actuel.

8. Encerclez TOUS les mots qui décrivent le mieux votre environnement de travail :
    a. Mal éclairé/sombre
    b. Bien éclairé
    c. Chaud
    d. Froid
    e. Humide
    f. Sec
    g. Glissant
    h. Terrain nivelé
    i. Terrain lisse
    j. Terrain accidenté
    k. Terrain meuble
    l. Autres descriptifs (indiquez-les) :

9. À votre avis, quels facteurs contribuent à votre risque de dérapage, perte d'équilibre ou chute? Indiquez-les ci-dessous :

10. Indiquez dans quelle mesure vous approuvez les énoncés ci-dessous.

	Tout à fait d'accord	**D'accord**	**Pas d'accord**	**Pas du tout d'accord**
L'**environnement de travail** contribue à mes risques de dérapage, perte d'équilibre ou chute.				
Mon degré de **fatigue** contribue à mes risques de dérapage, perte d'équilibre ou chute.				
Mon degré d'**hydratation** contribue à mes risques de dérapage, perte d'équilibre ou chute.				
Monter dans les engins et en descendre contribue à mes risques de dérapage, perte d'équilibre ou chute.				
Je suis **conscient(e) des facteurs de risque** de dérapage, perte d'équilibre ou chute sur mon lieu de travail.				

11. Complétez la phrase suivante. Je suis plus susceptible de glisser, perdre l'équilibre ou tomber _____. Encerclez **TOUTES** les réponses pertinentes.

    a. Au début de mon quart de travail
    b. Avant le repas du midi
    c. Après le repas du midi
    d. Vers la fin de mon quart de travail

12. À quelle fréquence vous déplacez-vous pendant votre quart de travail?
    a. Presque pas (moins de 7 min.)
    b. Rarement (7 min. – 36 min.)
    c. À l'occasion (37 min. – 3 h 59 min.)
    d. Fréquemment (4 h – 7 h 59 min.)
    e. Continuellement (8 h – 12 h)

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13. Au cours de votre vie, quel est le pire dérapage, la pire perte d'équilibre ou la pire chute qui vous est arrivé au travail dans une mine souterraine? Décrivez les conditions et ou événements qui sont à l'origine de l'incident. Si vous n'avez jamais eu ce genre d'incident, passez à la question suivante.

14. À quelle fréquence dérapez-vous, trébuchez-vous ou tombez-vous au travail?
    a. Jamais
    b. Rarement (1 par an)
    c. Occasionnellement (1 fois par mois)
    d. Fréquemment (1 fois par semaine)
    e. Assez souvent (plus de 2 fois par semaine)

15. Songez aux dérapages, pertes d'équilibre ou chutes que vous avez faits au travail au cours des 12 derniers mois et cochez **TOUTES** les cases pertinentes :

	Aucune aide (aucune blessure)	**Premiers soins** (légère blessure)	**Aide médicale**	**Accident avec perte de temps**
J'ai eu un **dérapage** qui a exigé				
J'ai eu une **perte d'équilibre** qui a exigé				
J'ai fait une **chute** qui a exigé				

J'ai eu une **combinaison de dérapage, perte d'équilibre et chute** qui a exigé				

16. Quelles bottes de travail portez-vous? Indiquez le fabricant (marque/modèle) si vous le connaissez.

Bottes à lacets en cuir

Marque/modèle : _____

Bottes en caoutchouc

Marque/modèle : _____

17. Est-ce que la lampe de votre casque possède un cordon?
    a. Oui
    b. Non

18. Pensez-vous que des articles de protection contribuent à votre risque de dérapage, de perte d'équilibre et de chute? Encerclez **TOUTES** les réponses pertinentes :
    a. Combinaison
    b. Pantalon et chemise à haute visibilité
    c. Bottes de travail en cuir à lacets
    d. Bottes de travail en caoutchouc sans lacets
    e. Respirateur à demi-masque
    f. Ceinture de mineur
    g. Lunettes de protection
    h. Casque
    i. Gants de travail
    j. Lampe de casque
    k. Autre (précisez) : _____

19. Aimeriez-vous changer un élément de votre matériel de protection personnelle? Si oui, précisez.
    a. Non
    b. Oui

20. Que recommanderiez-vous pour réduire le risque de dérapage, perte d'équilibre et chute au travail?

21. Quel facteur contribue le plus à votre risque de dérapage, perte d'équilibre et chute au travail? Classez **10** facteurs de 1 à 10 où 1 est le **plus grand** risque et 10 le **plus petit**.

Terrain accidenté		Lampes de casques	
Poids des bottes de travail		Mauvaise vision	
Mauvais éclairage		Lunettes de protection	
Vêtements à haute visibilité		Niveau d'hydratation	
Fatigue		Blessures précédentes	
Franchir de longues distances à pied		Bottes de travail glissantes	
Mauvais équilibre		Sentiers encombrés	
Flaques/trous		Surfaces glissantes	
Conscience du risque		Distraction	

Bottes de travail mal ajustées		Entrer/sortir des engins	
Autre (précisez) :		Autre (précisez) :	

22. Aimeriez-vous ajouter quelque chose au sujet de vos expériences de dérapage, pertes d'équilibre et chutes au travail et/ou des recommandations pour les prévenir?

Merci d'avoir pris le temps de répondre à ce sondage confidentiel sur les dérapages, les pertes d'équilibre et les chutes dans les mines souterraines.

Appendix F

Descriptive Statistics

Descriptive Statistics

	N Statistic	Minimum Statistic	Maximum Statistic	Mean Statistic	Std. Deviation Statistic	Skewness Statistic
Age	150	1	6	3.66	.968	-.125
Sex	152	1	2	1.02	.140	6.975
Height	150	55	80	70.07	2.992	-.686
Weight	148	115	325	208.61	39.274	.621
Position	152	1	7	3.78	2.058	.093
Experience	150	1	6	4.21	1.109	-.163
Poor lighting/dark	152	0	1	.80	.399	-1.536
Well lit	152	0	1	.24	.427	1.250
Hot	152	0	1	.87	.339	-2.202
Cold	152	0	1	.24	.431	1.208
Wet	152	0	1	.60	.492	-.407
Dry	152	0	1	.47	.501	.106
Slippery	152	0	1	.64	.482	-.581
Even terrain	152	0	1	.26	.438	1.126
Smooth terrain	152	0	1	.18	.383	1.704
Uneven terrain	152	0	1	.86	.346	-2.118
Loose terrain	152	0	1	.65	.478	-.641
Other	152	0	1	.26	.438	1.126
10 Environment	150	1	3	1.39	.517	.735
10 Fatigue	150	1	4	1.85	.689	.449
10 Hydration	149	1	4	1.99	.749	.109
10 Climbing	150	1	3	1.49	.576	.693
10 Awareness	150	1	3	1.41	.506	.541
11 Beginning	152	0	1	.52	.501	-.080
11 Before lunch	152	0	1	.35	.478	.641
11 After Lunch	152	0	1	.39	.490	.435
11 End	152	0	1	.81	.394	-1.590
Walking Frequency	150	1	5	3.53	.988	-.202
STF Frequency	149	1	5	2.83	.947	.778

	Skewness	Kurtosis	
	Std. Error	Statistic	Std. Error
Age	.198	-.393	.394
Sex	.197	47.267	.391
Height	.198	4.040	.394
Weight	.199	.480	.396
Position	.197	-1.331	.391
Experience	.198	.099	.394
Poor lighting/dark	.197	.364	.391
Well lit	.197	-.443	.391
Hot	.197	2.885	.391
Cold	.197	-.549	.391
Wet	.197	-1.859	.391
Dry	.197	-2.015	.391
Slippery	.197	-1.685	.391
Even terrain	.197	-.742	.391
Smooth terrain	.197	.915	.391
Uneven terrain	.197	2.520	.391
Loose terrain	.197	-1.610	.391
Other	.197	-.742	.391
10 Environment	.198	-.808	.394
10 Fatigue	.198	.081	.394
10 Hydration	.199	-.933	.395
10 Climbing	.198	-.503	.394
10 Awareness	.198	-1.337	.394
11 Beginning	.197	-2.020	.391
11 Before lunch	.197	-1.610	.391
11 After Lunch	.197	-1.835	.391
11 End	.197	.534	.391
Walking Frequency	.198	-.641	.394
STF Frequency	.199	.078	.395

	N Statistic	Minimum Statistic	Maximum Statistic	Mean Statistic	Std. Deviation Statistic	Skewness Statistic
S no assistance	152	0	1	.84	.366	-1.895
S first aid	152	0	1	.05	.224	4.047
S medical aid	152	0	1	.01	.081	12.329
S lost time claim	152	0	0	.00	.000	.
T no assistance	152	0	1	.75	.434	-1.166
T first aid	152	0	1	.04	.195	4.777
T medical aid	152	0	1	.02	.140	6.975
T lost time claim	152	0	0	.00	.000	.
F no assistance	152	0	1	.62	.487	-.492
F first aid	152	0	1	.03	.179	5.290
F medical aid	152	0	1	.01	.114	8.630
F lost time claim	152	0	0	.00	.000	.
C No assistance	152	0	1	.60	.492	-.407
C First Aid	152	0	1	.05	.210	4.375
C Medical Aid	152	0	1	.01	.114	8.630
C Lost Time Claim	152	0	1	.01	.081	12.329
Boot Type	147	1	2	1.37	.486	.526
Cap Lamp Cord	149	1	2	1.01	.082	12.207
Coveralls	152	0	1	.10	.299	2.718
High visibility pants and shirt	152	0	1	.01	.114	8.630
Lace up leather work boots	152	0	1	.11	.316	2.488
Slip on rubber work boots	152	0	1	.17	.378	1.765
Half face respirator	152	0	1	.07	.260	3.334
Miner's belt	152	0	1	.11	.316	2.488
Protective eye wear	152	0	1	.19	.394	1.590
Hard hat	152	0	1	.06	.237	3.773
Work gloves	152	0	1	.03	.161	5.978
Cap lamp	152	0	1	.40	.492	.407
Other	152	0	1	.19	.394	1.590
Change PPE	147	1	2	1.50	.502	-.014
Uneven terrain	152	0	11	2.15	2.465	2.090
work boot weight	152	0	10	1.82	3.391	1.582

Descriptive Statistics

	Skewness	Kurtosis	
	Std. Error	Statistic	Std. Error
S no assistance	.197	1.613	.391
S first aid	.197	14.570	.391
S medical aid	.197	152.000	.391
S lost time claim	.	.	.
T no assistance	.197	-.649	.391
T first aid	.197	21.101	.391
T medical aid	.197	47.267	.391
T lost time claim	.	.	.
F no assistance	.197	-1.781	.391
F first aid	.197	26.331	.391
F medical aid	.197	73.446	.391
F lost time claim	.	.	.
C No assistance	.197	-1.859	.391
C First Aid	.197	17.368	.391
C Medical Aid	.197	73.446	.391
C Lost Time Claim	.197	152.000	.391
Boot Type	.200	-1.748	.397
Cap Lamp Cord	.199	149.000	.395
Coveralls	.197	5.460	.391
High visibility pants and shirt	.197	73.446	.391
Lace up leather work boots	.197	4.245	.391
Slip on rubber work boots	.197	1.129	.391
Half face respirator	.197	9.236	.391
Miner's belt	.197	4.245	.391
Protective eye wear	.197	.534	.391
Hard hat	.197	12.395	.391
Work gloves	.197	34.180	.391
Cap lamp	.197	-1.859	.391
Other	.197	.534	.391
Change PPE	.200	-2.028	.397
Uneven terrain	.197	3.511	.391
work boot weight	.197	.836	.391

Descriptive Statistics

	N Statistic	Minimum Statistic	Maximum Statistic	Mean Statistic	Std. Deviation Statistic	Skewness Statistic
poor lighting	152	0	10	3.52	2.893	.674
High-visibility clothing	152	0	10	1.66	3.549	1.802
Fatigue	152	0	10	3.72	3.194	.409
Walking long distances	152	0	10	2.86	3.481	.857
poor balance	152	0	10	2.74	3.476	.860
puddles/holes	152	0	10	3.40	2.592	.821
awareness	152	0	10	3.47	3.708	.430
poor work boot fit	152	0	10	1.76	3.203	1.568
cap lamps	152	0	10	2.45	3.475	1.061
poor vision	152	0	10	3.24	3.474	.544
protective safety glasses	152	0	10	1.59	3.065	1.670
hydration level	152	0	10	2.36	3.272	1.007
previous injuries	152	0	10	2.18	3.461	1.249
poor grips on work-boots	152	0	10	2.23	3.286	1.185
clutter in walkways	152	0	10	3.18	3.259	.636
slippery surfaces	152	0	11	3.38	3.051	.662
distraction	152	0	10	3.59	3.854	.455
getting in/out of equipment	152	0	11	4.03	3.453	.356
other	152	0	11	.20	1.363	7.076
Valid N (listwise)	140					

Descriptive Statistics

	Skewness	Kurtosis	
	Std. Error	Statistic	Std. Error
poor lighting	.197	-.516	.391
High-visibility clothing	.197	1.400	.391
Fatigue	.197	-1.109	.391
Walking long distances	.197	-.699	.391
poor balance	.197	-.782	.391
puddles/holes	.197	-.020	.391
awareness	.197	-1.408	.391
poor work boot fit	.197	.937	.391
cap lamps	.197	-.468	.391
poor vision	.197	-1.227	.391
protective safety glasses	.197	1.249	.391
hydration level	.197	-.502	.391
previous injuries	.197	-.077	.391
poor grips on work-boots	.197	-.125	.391
clutter in walkways	.197	-.930	.391
slippery surfaces	.197	-.743	.391
distraction	.197	-1.470	.391
getting in/out of equipment	.197	-1.181	.391
other	.197	49.770	.391
Valid N (listwise)			

Appendix G

Description of the Main Tasks Performed by the Various Working Position

Position	Description	Position	Description
Drillers	• Set up and use of drills (ex. Jumbo jackleg, stopper, diamond drill) • Bolting & screening (installing ground support) • Scaling (using bar remove loose rock from walls) • Handling material (ex. Jackleg = ~100lbs) • Set up pump • Set up work area (loading gear on machinery, bringing materials to work area, etc.) • Hanging pipe, vent, etc. • Load blast • Climbing on/off equipment	Support Miners	• Install services, pipe, cable • Reconditioning • Service mine water and ventilation • Labour • Reduce dust • Maintain roadways • Handling tools and material (large pipe, vent tubing, etc.) • Deliver and pick up supplies • Muck • Operate forklift • Drive trucks • Climbing on/off equipment • Operate crusher
Operators	• Operate heavy equipment - Haulage truck - Scoop - McLean Bolter - Forklift - ANFO loader • Perform pre-operational inspection • Fuel equipment • Handle material • Haul ore • Move muck • Load rounds • Climbing on/off equipment	Other (Shotcreter, Bolter, Blaster, Welder, etc.)	• Spray shotcrete • Handle tools and materials • Install bolts and screen (ground support) using bolter • Scaling • Welding • Construction of walls • Cement work • Prep and load rounds (blasting)
Mechanics	• Service and repair heavy equipment - In shop and in field • Climbing on/off equipment • Handling of tools and materials • Drive equipment	Supervisors	• Walking to work areas (check on crew) • Driving to work areas (check on crew) • Deliver supplies • Inspecting work areas • Housekeeping • Assign and oversee tasks • Desk work