Comparison of parameters for likelihood and severities of injuries in artisanal and small-scale mining (ASM)

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Highlights

- Artisanal and Small-scale Mining (ASM) related injuries differs in degree of severity.
- The risk factors for likelihood of injuries are not necessarily same as those of severity of injuries.
- Reducing the likelihood of injuries can stop occurrence of severe injuries.

Abstract: Workplace injuries cause lost workdays, performance disability, incessant medical care and fatalities. Therefore, determining their risk factors helps in not only injury prevention but also their consequences. Although most of the researches concentrate on the likelihood of injuries, little research has been done to investigate the causes of severities. This study is an attempt to investigate the factors causing likelihood and severities separately and compare them to interpret their role

The present study used a survey design in order to encapsulate information pertaining to the risk factors and injury history. The structured survey questionnaire was administered to 162 uninjured and 74 injured miners in the Osiri Gold Mine. In addition, the methodologies of descriptive statistics and logistic regression were used to analyse the data.

The results showed that the laceration, contusion and fractures were common injuries, with most of them inflicting the hands and wrists, and were largely caused by dropped objects or equipment. When the risk factors for the likelihood of injuries and severity of injuries were examined, the following contributors were inferred: Male miners, less experienced miners, long shift hours as well as poor management and supervision, job dissatisfaction and job stress. The age group, drug usage, and poor work conditions were associated with likelihood of injuries but not with severity of injuries.

The study concludes that some risk factors for likelihood of injuries also influenced the severity of injuries. Therefore, it is advisable that sustained injury prevention mechanism must be instated to safeguard the welfare of miners.

Keywords: Artisanal and small-scale mining; Likelihood of injuries; Severe injuries; And risk factors

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1. Introduction

The demands for livelihood diversification in the rural areas of mineral-rich developing countries has pushed millions of men, women, and children to engage in Artisanal and Small-scale Mining (ASM) activities (Aizawa et al., 2016; Arthur et al., 2016; Hilson et al., 2009). For some miners, their socio-economic situation has considerably improved, but in the case of others, the activity has confined them to the vicious cycle of poverty (Buxton, 2013). ASM is defined as a type of mining that employs crude, primitive or low-tech equipment for mining metals and minerals through underground and open-cut mining approach, and it can be undertaken by an individual, a family, a community or a small-scale cooperative as means of improving living standard and gaining profit (Hentschel, 2003).

With modern society and advanced technology, ASM unlike large-scale operation is still characterised by rudimentary or semi-mechanised equipment, small capital, small production, environmental problems and poor occupational health and safety standards (OSH) (Hentschel, 2003). In addition, the activity is largely illegal and commonly practised in rural areas with limited or non-existing government surveillance – most countries globally have not formalized or if legalized, the laws are loosely enforced (International Labour Office [ILO], 1999). These complex webs of problems are often dominated by ASM positive socio-economic contributions (Fisher et al., 2009; Kamlongera et al., 2011).

The frequent occurrence of occupational injuries is one area of health concern that has captured the attention of policy-makers. In Tanzania, the statistics showed that 11 artisanal and small-scale miners died every year (Kitua et al. 2006). Recently carried out epidemiologic studies have firmly established that occupational injuries in ASM are prevalent and serious enough to cause significant post-injury consequences (Boniface et al., 2013; Calys-Tagoe et al., 2015; Elenge et al., 2013; Kyeremateng-Amoah et al., 2015).

Although physical/ergonomic hazards have being blamed for occupational injuries, there are additional underlying factors that influence the occurrence. Artisanal and small-scale miners worked in the environment where safety is completely disregarded (Bansah et al., 2016; Elenge et al., 2011). This is because the sector lack expertise, skills, proper investment and technological know-how to improve both production as well as safety.

According to the ILO, the sector is six to seven times more dangerous than large-scale mining (ILO, 1999). Poor safety culture has been identified to cause catastrophic accidental events in mining industry. The United States Nuclear Regulatory Commission (U.S.NRC) review a case-study carried out to understand the reasons behind mining accident in Upper Big Branch (UBB) mine in southern West Virginia, whereby twenty-nine coal miners were killed (U.S.NRC, 2012). The findings revealed that the company prioritized production over safety, poor environmental conditions, poor ventilation and coal dust which serve as a "catalyst to a resulting series of massive explosions". Correspondingly, some of the epidemiologic studies conducted in sub-Saharan African countries found majority of both injured and uninjured miners with no personal protective equipment (PPE) and lack health and safety training (Boniface et al., 2013; Calys-Tagoe et al., 2015; Elenge et al., 2013). The research also acknowledged high prevalent of hazards without available control mechanisms, poor management and lack of social support. Number of factors indicated positive or negative safety culture at workplace. In ASM operation, the key features of poor safety culture are poor working conditions, poor management and supervision, job stress and substance abuse.

The relationship between the indicators of poor safety culture at work and other risk factors such as individual characteristics with likelihood of occupational injuries has been well researched. However, with the likelihood of severe injury, these risk factors remain under-researched. Depending on the level of severity, occupational injuries are classified into non-recordable and recordable injuries. Non-recordable injuries are workplace injuries that have not resulted in lost workdays or medical attention, whereas recordable injuries are those that have led to a fatality, disability or medical care. The recordable injuries can be further sub-divided into the minor and severe injuries. Minor injuries refer to injuries that have led to only medical care or first aid, while severe injuries are related to recordable injuries that have caused incessant medical attention, disability, and fatality.

This study has focused on the risk factors associated with the likelihood of recordable injuries as well as likelihood of severe injuries in Artisanal and Small-scale Gold Mining (ASGM) operation in Osiri Mines of Migori County. As such, the study specifically has assessed: (i) the relationship between individual characteristics (age, gender, marital status, education level, and mining experience), behavioural-related risk factors (alcohol and drug usage) and job-related risk factors (shift hours, poor working conditions, poor management and supervision, job dissatisfaction and job stress) with likelihood of injuries. (ii) Do the predictors of likelihood of injuries also influence the severity of injuries?

2. Materials and Methods

2.1. Study area

This study was carried out in the Osiri Artisanal and Small-scale Gold Mining (ASGM) operations in Migori County. Migori County is situated in western Kenya, bordering Lake Victoria to the west and the Republic of Tanzania to the south. The county is known both in and outside of Kenya as a symbol of the gold mining activities (Ogola et al., 2002).

2.2. Participants and Sampling

The study population was 610 artisanal and small-scale gold miners. The data employed in the study was provided by the mine owners, worker representatives and validated by the research team, wherein, about 192 miners recorded injuries. The sample size for the present study was carried out using the Kathori’s (1990) formula. We first determined the population based on Z values, sample proportion and confidence level.

$$\text{Sample size} = \frac{Z^2 * \ (p) * q}{e^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots... [1]$$

- Z = Z value (e.g., 1.96 for 95% confidence level)

- Sample proportion, q = 1-p (p = 0.5 and q = 0.5)
- e = confidence level = (± 5%)

$$\text{Sample size} = \frac{1.96^2 * (0.5) * 0.5}{0.05^2} = \mathbf{384.16}$$

To reduce the sampling error, we corrected the finite population generated in equation 1. Whereby, N = number of current miners (both injured and uninjured) and SS = representative sample size.

$$SS = \frac{Z^2 * p * q * N}{e^2 (N-1) + Z * p * q} = \frac{Z^2 * p * q}{e^2}\left(\frac{N}{N - 1 + \frac{Z^2 * p * q}{e^2}}\right) = SS\left(\frac{1}{1 - \frac{1}{N} + \frac{SS}{N}}\right)$$

$$= \frac{SS}{1 + \frac{SS-1}{N}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [2]$$

Using equation 2, the representative sample for 610 miners is shown below.

$$SS = \frac{384.16}{1 + \frac{384.16 - 1}{610}} = \mathbf{236}$$

From the samples generated from equation 2, we adopted stratified random sampling for better sample representation. As a result, the study population was stratified into injured and uninjured stratum with 192 and 418 miners respectively. The samples within each group was calculated as follows:

$$\text{Stratum sample size} = \text{SS} * \frac{(\text{x})}{(\text{N})} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [3]$$

Whereby, SS = sample size determined in equation 2, x = population of injured or uninjured miners and N = overall population of miners. Therefore, the samples to select per stratum based on the proportional ratio is shown below:

$$\textbf{Number of injured miners } (y_1) = 236 * \left(\frac{192}{610}\right) = \mathbf{74}$$

$$\textbf{Number of uninjured miners } (y_2) = 236 * \left(\frac{418}{610}\right) = \mathbf{162}$$

The study only considered the participants who are miners, aged over 18 years and willing to provide free consent. Also, the mine owners, management and local government officials were excluded from the scope of the study.

The sampling approach adopted for conducting this study was stratified and systematic random sampling. The researchers developed the list of eligible miners and provided each of the study participants with pseudonym identifiers in order to safeguard their privacy and confidentiality. During the survey, the participants were segregated in two groups of injured and uninjured, for data collation. The starting random identifier for each group was selected by the research team, followed by the systematic selection of the remaining samples till the researchers reached the calculated target (74 injured and 162 uninjured participants). This approach was adopted for the dual purpose of (i) providing a better representation of the population and (ii) reduced sampling error.

2.3 Structure of the survey instrument

In the current paper, survey design has been used in order to achieve the objective of the present study. The survey was employed because of the time, resources and lack of reliable data on ASM recordable injuries.

The study used a structured closed-end questionnaire that was divided into four sections. The section one included questions relevant to the demographic profile of the participants, i.e., age, gender, marital status, education level, mining experiences and hours worked per day. Section two included questions, which sought information as regards the level of alcohol and drug consumption. That is, the participants were asked whether they come to work intoxicated; consumed substance before, during or after; whether they have experienced near misses and/or have been involved in accidents that hurt them or some else. The third section took into account the miners' perception about poor working conditions, poor management and supervision, job dissatisfaction and job stress. The fourth and the last section of questionnaire was restricted specifically to 74 miners with recordable injuries and entailed questions about the number of days spend off work, whether the experience limited their job performance, resulted in continuous body pain and warranted medical attention.

The reliability and validity of the data collection (structured closed questionnaire) were assessed before implementing the study (Heale et al., 2015). The reliability was achieved by calculating the Cronbach's alpha from pilot testing data. Our calculated Cronbach's alpha was 0.786 which is greater than an absolute minimum of 0.7 (Hinkin et al., 1998). For validity, we consulted one of public health expert with strong background in public health data collection procedures and instrument design in Migori County. The expert concluded that variables that underpinned the content were considered in the tool and it was valid for current study.

2.4 Data collection procedure

The participants were contacted and identified through disseminating verbal information through word of mouth and flyers. Prior to initiating the data collection, the primary researcher recruited two research assistants who were conversant with the native language and skilled in public health data collections. The research assistants were subsequently trained on the survey instrument as well as the ethical conduct of the research. Also, this initial spadework included extensive consultation and sensitization with various stakeholders including miners to obtain permissions, inform, validated number of miners and registered the willing participants.

During the survey, each eligible participant was informed of the purpose of present study and provided with an informed consent form to sign or place their thumbprint impression, expressing their voluntary participation. The literate participants were allowed to self-administer the questionnaires, while semi-literate or illiterate participants were assisted by the research team. For these participants, the survey questions and answers were read out, and specific care exercised in order to prevent directing or influencing their responses. The completion of the questionnaire was carried in either English, Kiswahili or Luo language depending on the participants' preferred language. Each questionnaire took about 30-40 minutes to be completed.

2.5 Data preparation

The collected survey questionnaires were critically reviewed, and those filled in Kiswahili or Luo language were translated back to English for uniformity of response language. The clean dataset was subsequently entered and coded in SPSS software. The study collated and segregated the response under the variables of: (i) likelihood of injuries; and (ii) severity of injuries. The likelihood of injuries was further coded into the classifications of (i) No = 0, and (ii) Yes = 1. This classification was based on whether the participants did face injury or not. The severity of injuries was operationalized through number of lost workdays. The participants who reported to have stayed off work less than a week (1-6 days) after getting injured were merged in no injured group and coded as 'No = 0'. While those that had over a week (7 days) lost workdays were categorised as 'Yes = 1'. Correspondingly, the individual characteristics, behavioural-related risk factors, and job–related risk factors were coded as shown in Table 1.

Table 1 presents the injury summary statistics of the injured participants in Osiri Gold Mines based on the cross-tabulation of the interested response variables, namely, the likelihood of injuries and severity of injuries.

Table 1. Participants' response to risk factors for both likelihood of injuries and severity injuries (N= 236)

Risk factors	Likelihood of injuries (%)		Severity of injuries (%)	
	No (N= 162)	Yes (N= 74)	No (N = 176)	Yes (N = 60)
Age groups				
1= 18-34	51.9%	68.9%	54.0%	66.7%
2= 35 and over	48.1%	31.1%	46.0%	33.3%
Gender				
1= Male	51.9%	67.6%	52.8%	68.3%
2= Female	48.1%	32.4%	47.2%	31.7%
Marital status				
1 = Single	42.6%	51.4%	43.8%	50.0%
2 = Married	57.4%	48.6%	56.3%	50.0%
Level of education				
1= Low education level (< Year 8)	60.5%	75.7%	60.8%	78.3%
2= High education level (> Year 8)	39.5%	24.3%	39.2%	21.7%
Mining experiences				
1= Less than 3 years	54.3%	70.3%	55.1%	71.7%
2= More than 3 years	45.7%	29.7%	44.9%	28.3%
Shift hours				
1= More than 8hrs/day	44.4%	67.6%	46.0%	68.3%
2= Less than 8hrs/day	55.6%	32.4%	54.0%	31.7%
Alcohol consumption				
1= High-risk user	58.0%	54.1%	58.0%	53.3%
2= Low-risk user	25.3%	29.7%	26.7%	26.7%
3= Not alcohol user	16.7%	16.2%	15.3%	20.0%
Drug usage				
1= High-risk user	24.1%	45.9%	26.1%	45.0%
2= Low-risk user	40.1%	23.0%	38.6%	23.3%
3= Not drug user	35.8%	31.1%	35.2%	31.7%
Poor work condition				
1= Agree	55.6%	77.0%	57.4%	76.7%
2= Disagree	44.4%	23.0%	42.6%	23.3%
Poor management and supervision				
1= Agree	70.4%	83.8%	71.0%	85.0%
2= Disagree	29.6%	16.2%	29.0%	15.0%

Job dissatisfaction				
1= Agree	61.1%	78.4%	62.5%	78.3%
2= Disagree	39.9%	21.6%	37.5%	21.7%
Job stress				
1= Agree	78.4%	90.5%	79.5%	90.0%
2= Disagree	21.6%	9.5%	20.5%	10.0%

Table 1 presents the injury summary statistics of the injured participants in Osiri Gold Mines based on the cross-tabulation of the interested response variables, namely, the likelihood of injuries and severity of injuries.

For alcohol and drugs (i.e., marijuana, opium, etc.) usage, the study primarily focused on the risk associated with consumption and intoxication levels. Based on the responses to the questions, the researchers were able to ascertain the risk level, basis which the miners were classified into high-risk users, low-risk users and non-users. Miners who did not consume substances at all were categorised as ‘not a user’, while those who consumed alcohol but did not come to work intoxicated or took substances at work were considered as ‘low-risk users’. Lastly, miners who came to work intoxicated, consumed substances at work, were involved in accident, experienced near misses or got injured because of substances were coded as ‘high-risk users’.

Job-related factors were originally assessed using the 5-Likert scale and subsequently reorganised into two categories – agree and disagree. Each variable Likert item was summed up against the rest and allocated the category depending on the mean. Following which, the ‘strongly agree’ was merged into ‘agree while ‘neutral’, ‘disagree’ and ‘strongly disagree’ into ‘disagree’, as determined by the response sizes. The combination of 5-Likert items into 2-Likert items was necessitated by the sample size and effects on the model. The logistic regression analysis demonstrated that the events per variable (EPV) must be > 20 (Peduzzi et al., 1995). However, Vittinghoff et al. (2007) stated that 5-9 EPV were enough to reduce the instability of the predictive model.

2.5 Statistical analysis

The clean and coded data was first analysed using the descriptive statistics, wherein the frequency distributions and percentages of risk factors and injury history were determined. This was followed by the bivariate and multivariate logistic regression analysis to assess risk factors for likelihood of injuries and severity of injuries.

The association analysis test was conducted in two stages: The first involved assessing and establishing the relationship between risk factors and likelihood of injuries. The second stage entailed assessing and establishing the severity of injuries predictors.

In the first stage, the bivariate relationship between the various risk factors and likelihood of injuries was conducted using binary logistic regression. The test was aimed to identify the risk factors through Crude Odds Ratio (COR) at 95% Confidence Interval (CI). The risk factors were then used in the multivariate logistic regression model and backward elimination was performed. In this form of analysis, risk factors that have p > or = 0.1 are continuously eliminated until all significant factors were achieved. Participants' age group and alcohol consumption were eliminated during this analysis. The risk factors with $p<0.05$ were considered as significant for likelihood of injuries.

In the second stage, the experimental work followed the same procedure as in stage one, but herein the focus was more on risk factors associated with the severity of injuries. The bivariate test association was performed between the risk factors and severity of injuries, of which crude odds ratios (CORs) at 95% CI were computed. Again, the binary logistic regression model was saturated with all the risk factors. We, then manually removed the risk factors that were insignificant in the model until we were left with only significant predictors of severity of injuries, which produced AOR at 95% CI. Marital status, alcohol consumption, age group, drug usage and poor working conditions were removed.

3. Results

3.1. Recordable injuries characterization

Artisanal and small-scale gold miners were observed to have suffered a variety of injuries as shown in Fig. 1 below. Of the 169 injuries self-reported by the participants, 28% of cases were of laceration injuries, followed by contusion injuries with 17% and the least occurring were facial and burn injuries with 1% respectively.

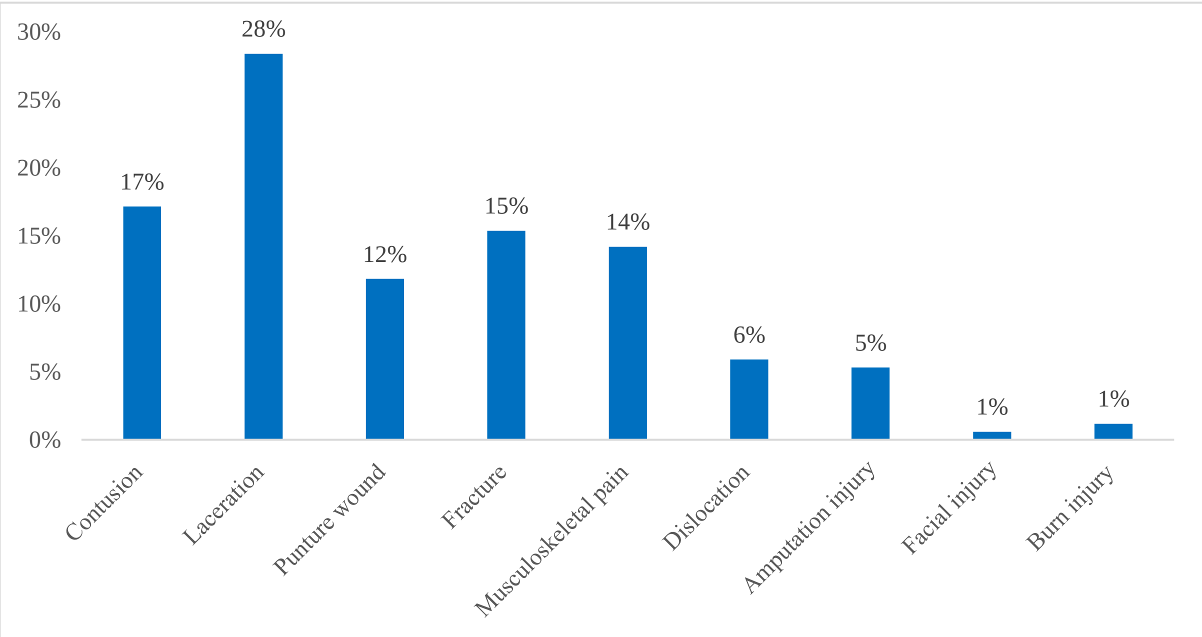

Fig. 1. Nature of injuries

3.2. Body part injured

Figure 2 showed that many of participants sustained injuries on their hands and wrists (17%), with almost equal (12%) proportion having injuries around their shoulder, back, arms and elbows, thumbs and legs. Whereas, neck, faces and hips sustained very few injuries.

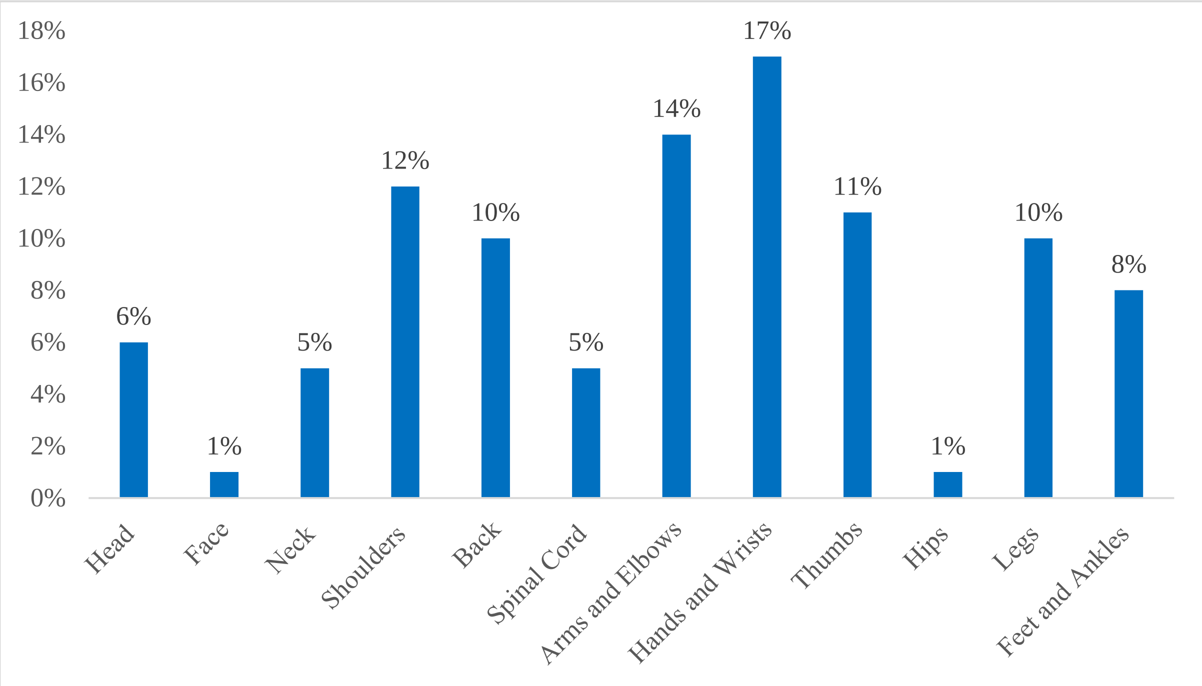

Fig. 2. Body parts injured

3.3. Mechanism of causation of injuries

Figure 3 shows the various causes of injuries sustained by the miners during work. It is observed that the main cause of injury was being struck by an object (38%) and/or work equipment (30%). While the chemicals (1%) and explosions (1%) caused minimal injuries among the miners.

3.4. Determination of severity of injuries

The severity of injuries was assessed through the measurement of the number of lost workdays. Figure 4 represents number of participants involved in different lost workdays due to injury. Of the 74 survey injured participants, those that have stayed off work for a duration exceeding 30 days were majority, followed by a range of 14-29 lost work days. The participants who reported the loss of 1-6 workdays were in minority proportion.

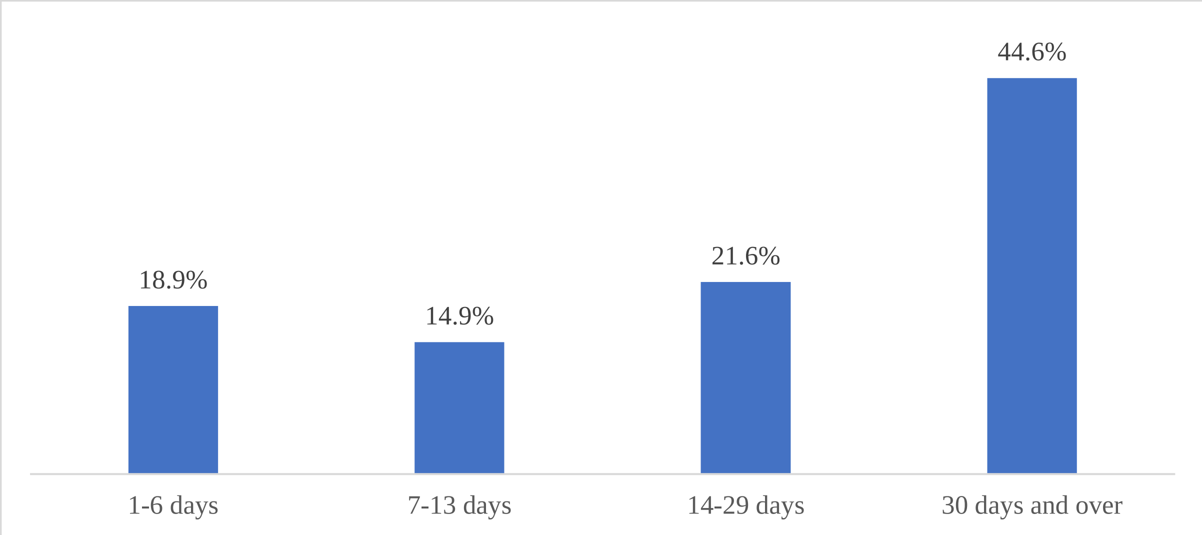

Fig. 4. Injuries based on number of lost workdays

3.5. Participants' injury condition

Participants were asked about their injury conditions with the purpose to evaluate whether they are continuing to encounter some work-related problems. This objective helped in understanding severity of injuries in ASM operation. Herein, about 43.24% of the respondents (i.e., a majority percentage) reported to have been restricted sometimes by their injuries from performing their daily activities; while 31.08% reported conversely and 25.68% participants reported a continued restriction due to their injuries from performing their daily activities. The questions pertaining to explore whether the respondents had experienced any other distress/pain that affected their body movements apart from visible physical injury, 50% of the respondents (i.e., a majority percentage) had not experienced any other distress/pain that affected their body movements apart from visible physical injury while 50% reported in opposition.

The study also sought to evaluate whether the respondents had seen a doctor or any medical practitioner due to the pain from the injuries endured. As indicated in Table 2, 54.05% (i.e., a majority respondent percentage) had not seen a doctor or any medical practitioner due to the pain from the injury while 45.95% reported contrariwise. On the parameter of pain affecting a restricted job performance, 47.30 % of the respondents (i.e., the majority) indicated that their job performance had not been restricted at all by the pains, while 28.38% indicated that their job performance had sometimes been restricted by the pains whereas 24.32% indicated that their job performance had always been restricted by the injury-induced pains.

Table 2. Participants' responses on job performance, bodily pain and medical attention

Characteristics	Frequency distribution (n=74)	Percentage
Injury restricting daily job performance		
Not at all	20	27.00
Sometime	32	43.20
Always	22	29.70
Body pains from Injury		
Yes	37	50.00
No	37	50.00
Seen the doctor or any medical practitioner		
Yes	33	44.60
No	41	55.40
Pain restricted job performance		
Not at all	35	47.30
Sometime	23	31.10
Always	16	21.60

3.6. Model Accuracy

In logistic regression, several ways for measuring the observed and the fitted values are common (Hosmer, 2000). However, these models depend on the type of the logistic regression adopted in the study. Hosmer and Lemeshow test is one of the frequently used goodness-for-fit test in binary logistic regression. SPSS has built-in function for determining Hosmer and Lemeshow test. In this test, $p<0.05$ (significant level) indicates that the model does not fit the data while $p>0.05$ (significant level) indicates that the model fit the data adequately. Hosmer and Lemeshow test has similar characteristics as Chi-square accuracy test. The model of likelihood of recordable injury and severity of injury has returned $p > 0.05$ as shown in Table 3 and 4 therefore, the research concluded that the model fitted the data accurately.

Table 3. Hosmer and Lemeshow Test of likelihood of recordable injuries

Chi-square	df	Sig.
8.758	8	.363

Table 4. Hosmer and Lemeshow Test of likelihood of severe injuries

Chi-square	df	Sig.
6.575	8	.583

3.7. Risk factors for likelihood of injuries

Table 5 presents the results of bivariate and multivariate analysis to observe the risk of likelihood of injuries. The results showed that younger age group, male miners, less experienced miners, working for longer hours, high-risk drug users, perceived poor working conditions as well as poor management and supervision, job dissatisfaction and job stress were strongly associated ($p<0.05$) with likelihood of injuries. In the backward elimination, the marital status, alcohol consumption and education were found insignificant, and as a result, they were removed from the model. Therefore, Table 5 showed only risk factors that predict likelihood of injuries in ASM operation.

Table 5. Risk factors that predicts likelihood of injuries in ASM operation

Risk factors	COR (95% CI)	AOR (95% CI)	Multivariate p-value
Age groups			
1= 18-34	2.06 (1.15 – 3.68)	2.03 (1.03– 4.03)	0.042
2= 35 and over [RC]			
Gender			

1= Male	1.94 (1.09 – 3.44)	2.61 (1.31– 5.20)	0.006
2= Female RC			
Mining experiences			
1= Less than 3 years	1.99 (1.11 - 3.57)	2.19 (1.10 - 4.36)	0.026
2= More than 3 years RC			
Shift hours			
1= More than 8hrs/day	2.60 (1.46 – 4.64)	2.34 (1.20 – 4.55)	0.012
2= Less than 8hrs/day RC			
Drug usage			
1= High-risk user	2.20 (1.13 – 4.28)	2.22 (1.02 – 4.85)	0.045
2= Low-risk user	0.66 (0.32 – 1.36)	0.57 (0.25 – 1.30)	0.183
3= Not drug user RC			
Poor work condition			
1= Agree	2.68 (1.44 – 5.00)	2.34 (1.14 – 4.83)	0.021
2= Disagree RC			
Poor management and supervision			
1= Agree	2.18 (1.08 – 4.40)	2.58 (1.14– 5.85)	0.024
2= Disagree RC			
Job dissatisfaction			
1= Agree	2.31 (1.22 - 4.36)	2.17 (1.04 – 4.51)	0.038
2= Disagree RC			
Job stress			
1= Agree	2.64 (1.11- 6.26)	3.16 (1.18 – 8.51)	0.023
2= Disagree RC			

$p < 0.05$ represents positive relationship between risk factor, while $p > 0.05$ represents no association. COR represents test association between single risk factor and response variable. While AOR represents contributing effect of multiple risk factors with response variable.

3.8. Risks factors for severity of injuries

In this part of analysis, we have assessed whether the risk factors for likelihood of injuries are also predictors of the severity of injuries. The comparison has revealed that the majority of risk factors for likelihood of injuries except age group, drug usage and poor working conditions also predict severity of injuries. All risk factors except education level, which have been found to predict severity of injuries, are also associated with likelihood of injuries as shown in Table 6.

Table 6. Risk factors associated with likelihood of severe injuries

Risk factors	COR (95% CI)	AOR (95% CI)	Multivariate p-value
Gender			
1= Male	1.93 (1.04 – 3.58)	2.15 (1.09 – 4.21)	0.026
2= Female [RC]			
Level of education			
Low education level (< Year 8)	2.33 (1.18 – 4.62)	2.51 (1.20 – 5.26)	0.014
High education level (>Year 8) [RC]			
Mining experiences			
1= Less than 3 years	2.06 (1.09 – 3.89)	2.20 (1.11 – 4.38)	0.024
2= More than 3 years [RC]			
Shift hours			
1= More than 8hrs/day	2.53 (1.36 – 4.70)	2.32 (1.20 – 4.51)	0.013
2= Less than 8hrs/day [RC]			
Poor management and supervision			
1= Agree	2.31 (1.06 – 5.04)	2.70 (1.17 – 6.21)	0.020
2= Disagree [RC]			
Job dissatisfaction			
1= Agree	2.17 (1.09 – 4.31)	2.17 (1.04 – 4.53)	0.040
2= Disagree [RC]			
Job stress			
1= Agree	2.31 (0.92 – 5.80)	2.68 (1.00 – 7.18)	0.051
2= Disagree [RC]			

$p < 0.05$ represents positive relationship between risk factor, while $p > 0.05$ represents no association. COR represents test association between single risk factor and response variable. While AOR represents contributing effect of multiple risk factors with response variable.

4. Discussion

The objectives of this research were to identify the risk factors for likelihood of injuries and severe injuries separately and provide explanation for any differences. Prior to the assessment of relationships, we characterized the recordable injuries, lost workdays and injured participants' present health conditions. Our results showed that the most frequent occurring recordable injuries among the gold miners in Osiri were: Laceration injuries, contusion injuries, fracture injuries and musculoskeletal pain. Correspondingly, as per the collated responses of many participants, these injuries mainly were inflicted on their hands and wrists, arms and elbows, shoulders, legs, thumbs, feet and ankles, head and back. The causal mechanisms of these injuries included, being struck by the object, equipment, heavy loads and/or slip/trip fall. Similar findings have been deduced by few limited studies, which were carried out in other sub-Saharan African countries (Boniface et al., 2013; Calys-Tagoe et al., 2015; Elenge et al., 2013; Long et al., 2015), whereby occupational injuries were found to cause severe injuries. The present and past findings can thus be safely inferred to support the hypothesis that indeed ASM operators are susceptible to occupational injuries with varying degrees of severity. The widespread of these injuries among the miners is attributed to the nature of equipment and conditions of the work environment.

The summary analysis of lost workdays revealed that 60 cases fitted the definition of severe injuries while 14 cases were related to minor injuries. These 14 cases were combined with no injury group for the relationship analysis. In spite of studies carried out to understand the widespread presence of workplace injuries in ASM, there is lack of evidence regarding the relationship between the risk factors for likelihood of injuries and likelihood of severe injuries. Severe injuries often resulted in elongated medical attentions, job performance restrictions, disability and fatality. Therefore, it is significant for injury prevention purpose to compare the risk factors for the likelihood of injuries and likelihood of severe of injuries.

We discuss risk factors that influence likelihood of injuries or likelihood of severe injury only in section 4.1 and 4.2 respectively. In section 4.3, we discuss the risk factors that contribute to both likelihood of injuries and likelihood of severe injuries.

4.1. Exclusive predictors of likelihood of injuries

Our study revealed that younger age group (18-34) had higher risk (AOR 2.03, $p<0.05$) of occupational injury than older age group (> 35 years).   On contrary, when age group was evaluated against the likelihood of severe injury, we found it is insignificant ($p>0.05$) and therefore, was removed from the model to achieve accuracy. These findings are in line with previous studies that associated younger age group with injury occurrence but not likelihood of severe injury (Laflamme et al., 1996; Stojadinovic et al., 2012). This is because younger workers compared to older workers tend to be less experience in hazard identification and management and have recklessness behaviour. However, when it comes to severity of injuries, younger workers have increased body strength and mental ability to recover quicker, thus, suffer less severe injuries (Laflamme and Menckel, 1995).

The research also revealed that the high-level drug users had higher risk (AOR 2.22, $p<0.05$) for the likelihood of injuries than others, but it is not significant ($p>0.05$) for likelihood of severe injuries. This showed that drug usage can reduced concentration, alertness, judgement and impaired performance but not necessarily severe injuries. This study agrees with the research conducted in the United States, wherein, it was found that drugs impacted 25% increase in the occupational accidents among the male workers (Bena et al., 2013). Another study conducted in North Eastern France found drug use as one of the risk factors that accelerate the occupational injuries risk among the employed people (Bhattacherjee et al., 2003).

Our study examined miner's perception about the ASM working conditions. The variable "poor work condition" was measured by whether miners had health and safety training, used personal protective equipment, had injury due to physical and ergonomic hazards. The multivariate regression analysis showed that miners that agreed to these factors had higher risk (AOR 2.34, $p<0.05$) than those disagree. Thus, it is revealed that poor working conditions increases the likelihood of injuries but not necessarily likelihood of severe injury. Corresponding studies in ASM operation have evidence of presence of hazards, lack of personal protective equipment (PPE) and poor management and supervision and increased level of workplace injuries (Boniface et al., 2013; Calys-Tagoe et al., 2015; Elenge et al., 2013; Long et al., 2015).

4.2. Exclusive risk factors to likelihood of severe injury

Our study found that only one risk factor (miners' education) is exclusively responsible for likelihood of severe injury but not for likelihood of injuries. Low educated miners (< Year 8) had high risk (AOR 2.51, $p<0.05$) of suffering severe injury than others with higher education (> Year 8). Corresponding studies concluded similar findings despite differences in ORs (Boniface et al., 2013, Stojadinović et al., 2012). The present and past findings can be attributed to the fact that many ASM miners are uneducated or have little education, as a result, commonly work as laborers compared to highly educated miners who work in a less risky environment such as office areas.

4.2. Predictors of both likelihood of injuries and severity of injuries

Our results showed that the following risk factors associated with likelihood of injuries also influenced the likelihood of severe injuries: (i) Gender, (ii) experience, (iii) shift hours, (iv), poor management and supervision, (v) job dissatisfaction, and (vi) job stress.

The multivariate analysis showed that male gender had higher (AOR 2.61, $p<0.05$) risk of occupational injury than female gender, but when tested with likelihood of severe injury, the risk was less (AOR 2.15, $p<0.05$). In a study conducted in Zimbabwe, it was found that male miners were 15.3 times more likely to suffer severe injuries compared to female miners (Chimamise et al., 2013). Another study conducted in the Amhara region state of Ethiopia also demonstrated that males were 2.54 times more likely to experience severe injuries (Aderaw et al., 2011). According to these researchers, male workers are more 'inclined to risk taking behaviour', resultantly, exposing themselves to varying degrees of occupational injuries. This reason holds good for this study as well, as male miners were observed to engage in riskier duties such as using rudimentary equipment to dig in the unventilated and unlit working areas while women worked in open space with less labour-intensive duties.

Regarding mining experience, the multivariate results suggested that less experienced miners (< 3 years) had higher risks (AOR 2.19, p<0.05) of occupational injury than more experienced miners (> 3 years). The analysis with the likelihood of severe injury showed less risk (AOR 2.20, p<0.05)-between the groups. Previous studies have used different cut-off points in regard to the criteria for classifying miners as less experienced; however, a consistency is apparent across the board that the less experienced workers suffer from frequent injuries with varying degree of severities (Aderaw et al., 2011; Boniface et al., 2013; Calys-Tagoe et al., 2015). This can be attributed to the fact that inexperienced miners are less aware of the new working environment, its associated hazards and necessary safety measures.

In terms of shift hours, the findings delineate that miners who worked more than 8 hrs/day were inclined to experience injuries which are mostly severe. The study found miners that worked longer hours had higher risk (AOR 2.34, p<0.05) for likelihood of injury than others. However, the risk dropped (AOR 2.32, p<0.05) when assessed with the likelihood of severe injury. In this regard, Chimamise et al. (2013) found that working more than 8 hrs per day causes severe injuries because working long hours reduced the focus and concentration of the workers. Several studies conducted previously have concluded the same findings (Dembe et al., 2005; Salminen, 2010). This is attributed to the fact that extended working hours resulted in fatigue, reduced concentration and consequentially severe injuries.

In the analysis of job-related risk factors, the results showed that perception of poor management and supervision was significant association with likelihood of injuries as well as likelihood of severe injury. The variable “management and supervision” were assessed by relationship between the workers and leadership, social support, recognition and work schedule. Participants that negatively agreed to these indicators had higher risk (AOR 2.58,

$p<0.05$) for likelihood of injuries than others. However, with the likelihood of severe injury, the risk increased (AOR 2.70, $p<0.05$). According to several studies, poor perception of management and supervision are manifested through the lack of safety training, poor equipment, lack of policies and social hazards, presence of hazards without proper control mechanisms (Calys-Tagoe et al., 2015; Chimamise et al., 2013). When leadership fails, the risk of occupational accidents and outcomes become frequent and severe (Sawacha et al., 1999). During a casual discussion with mine operators, they revealed that the inadequate health and safety measures in their working area were due to poor leadership. According to them, safety is the last thing in their supervisors' mind, and they are pushed to increase production. As a result, many of them have suffered minor and major injuries.

Our study also found that job dissatisfaction was associated likelihood of injuries and severity of injuries. Job dissatisfaction is a miners' negative feeling toward their work conditions. Participants that have bad relationship with their superior, had negative feeling about work conditions, do not receive recognitions, have no social supports, are not satisfied with earnings and believe that present job is bad for their health had higher risk (AOR 2.17, $p<0.05$) for likelihood of injuries as well as likelihood of severe injury. The same risk indices were surprising, given the variance revealed by other study variables. A study carried out among underground coal miners in India also revealed higher risk indices among the highly job dissatisfied workers compared to less job-dissatisfied workers (Paul et al., 2005). Similar conclusion was drawn by McCaughey et al. (2014), whereby those who experienced job-related injuries were less satisfied.

Job stress was another risk factor that was of interest in this study. Our findings revealed that miners who agree to experiencing job stress in ASM operation had higher risk (AOR 3.14, $p<0.05$) for likelihood of injuries. When this risk factor is tested against the likelihood of severe injury, we found that the risk dropped (AOR 2.68, $p<0.05$). Other studies have evidenced that excessive workload, extended working hours, poor working environment, poor management and supervision, and job dissatisfaction produced stress and subsequently occupational injuries (Ghosh et al., 2004; Amponsah-Tawiah et al., 2013; Nakata et al., 2006). This study upholds this inference, as manifested by the study findings of a strong association between the shift hours and poor management and supervision with likelihood of injuries.

5. Discussion on limitations and future research directions

Although ASM operation continues to operate with rudimentary or semi-mechanised equipment and predominately is located in rural areas of developing countries, our study recommends for future studies to look into how modern society and technological-economic complex system affect health and safety of miners and nearby communities. In addition, the impact of external factors like the complexity on the performance and risks of various socio-technological-economic systems are not considered. We also recommend further studies to investigate the organizational and human performance as well as motivational and cognitive biases and their significant impact on the ASM safety.

If possible, the future research should be supplemented with participants' medical records. This will help to validate the number and severity of injuries, period of treatment rather than relying solely on the self-report. Moreover, interviews with local health officers, worker representatives, mine owners and government officials are recommended to ascertain the risk level.

6. Conclusions

The present study has shown that the recordable injuries in ASM operation ranged from minor injuries to severe injuries. Previously, greater attention was paid to the risk factors associated with likelihood of injuries, with limited focus on likelihood of severe injury. The analysis of risk factors for likelihood of injuries and severity of injuries independently and comparing them provide insight into why there are more severe injuries in ASM operation or other workplaces. This information is critical for injury prevention and post-injury socio-economic and psycho-social consequences management. Our study has demonstrated that majority of risk factors for the likelihood of injuries also predict severity of injuries.

Ethics consideration

This study was approved by the Curtin University Human Research Ethics Committee (HRE2017- 0534), Strathmore University Institutional Review Board (SU-IRB 0163/18) and Government of Kenya (Permit No. NACOSTI/P/18/13815/21845).

Declaration of interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this research paper.

Submission declaration and verification

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Authors' contributions

Mr. Michael Mayom Ajith and Dr. Apurna Kumar Ghosh both contributed substantially to the submitted work and has reviewed and agrees with the submission of the manuscript for review.

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