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Original Article

Risk Factors for the Number of Sustained Injuries in Artisanal and Small-Scale Mining Operation

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A B S T R A C T

Background: The relationship between risk factors and likelihood of occupational injury has been studied. However, what has been published has only provided a limited explanation of why some of the employees working in the same environment as other employees suffered a single-injury event, while other employees experienced multiple-injury events. This article reports on an investigation of whether artisanal and small-scale miners in Migori County of Kenya are susceptible to a single-injury or multiple-injury incidences, and if so, what underpinning parameters explain the differences between the single incident injured and the multiple incident injured group. Mine management commitment to safety in artisanal and small-scale mining (ASM) operations is also considered.
Materials and methods: The research objectives were achieved by surveying 162 uninjured and 74 injured miners. A structured, closed-end questionnaire was administered to participants after the stratification of the study population and systematic selection of the representative samples.
Results: The results showed that most injured miners suffer a single-injury incident rather than experiencing multiple-injury events, and laceration (28.40%) was the common injury suffered by the miners. The analysis showed that the risk factors for the single incident injured group were not similar to those in the multiple incident injured group. The research also found mine workers have low opinion about mine management/owners commitment to safety.
Conclusion: The study concluded that mine management and miners need to be educated and sensitized on the dangers of this operation. Provision of safety gears and positive safety culture must be a top priority for management.

1. Introduction

Occupational health and safety in the mining industry has significantly improved in recent years; however, still more needs to be achieved to ensure work can be accomplished without health-related problems [1]. The mining methodology practised particularly in large-scale mining (LSM) operations continues to change with improved safety focus [2]. Technological improvement, automation and tightened regulations, and increased companies' commitment to safety have positively impacted operational philosophy [3]. Previously, companies consider production more important than safety. However, this operational emphasis has shifted to what many companies in developed nations called "safe tonnages". Mine safety has become an integrated part of sustainable production [3].

Although artisanal and small-scale mining (ASM) activity is an important source of livelihood among the impoverished people in developing nations, the sector has not achieved health and safety improvements similar to LSM [4]. The risk of accident in ASM is believed to be 6–7 times higher than that in LSM, and women and children are 90 times at risk of fatality [5]. The published work of Elenge et al. [6] and Bansah et al. [7] carried out in the Democratic Republic of Congo and Ghana, respectively, established that people working in ASM operations are exposed to various hazards with notable serious health implications. The authors attributed current state of ASM conditions to illegal operations, unsafe acts, and poor

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safety culture, as well as lack of mine owners' or companies' commitment to health and safety. Smith et al. [4] also highlighted similar problems and emphasized knowledge building and sensitization of mine workers and other stakeholders on health and safety risks.

ASM operation is predominately located in mineral-rich rural areas of developing nations [8]. In many of these countries, about 70–80 % of mine workers operate illegally [3]. Bansah et al. [7] found that government agencies do not monitor and enforce rules and regulation in small-scale underground mines of Ghana. Resultantly, miners were found to operate without licenses. Similarly, Smith et al. et al. [4] call for proper regulation for ASM operation after implementing participatory action research [9] among the scholars, practitioners, and mine inspectors, and found mine workers operating extra legally. In alignment, a plethora of published literature has evidenced ASM miners as disapproving government initiatives to formalize the sector [10–12]. However, without formalization, the sector continues to contribute to damaging socioeconomic situation, environmental degradation, and health and safety problems [3].

Despite the complex web of problems linked to the ASM sector, the available published literatures on health and safety are dominated by occupational illnesses and their contributors, with limited publications on injuries and underlying causes. The studies that have specifically investigated the injuries that happened in ASM operation cited this problem to be a common phenomenon [13–19]. These publications have revealed that ASM-related injuries vary in severities (simple injuries to major physical traumas), with some evidencing frequency of occurrence (single-injury or multiple-injury events). Although the present findings have provided valuable insight into the nature, bodily distribution, and causation mechanisms of ASM-related injuries, these studies have failed to explain *why some of the employees working in the same environment as other employees suffered a single-injury event, while other employees experience multiple-injury events*?

So far, in accordance with the available research, the factors for mining-related injuries fall under two categories: (i) individual factors and (ii) work environment and work practices factors [20]. The individual factors are the demographical and behavioral characteristics, while work environment and work practices factors are incidents related to job hazards and organization factors [21]. The commonly cited demographical and behavioral characteristics are age group, gender, marital status, education level, experience, alcohol, and drugs. The association of these risk factors with occupational injury continues to generate debate. Some studies argued that these demographical and behavioral factors influence the risk of injuries while others demonstrated opposing opinions. Similarly, work environment and work practices factors such shift hours, poor work conditions and environment, poor management and supervision, job dissatisfaction, and job stress have been mentioned to be significant or insignificant with the risk of occupational injuries.

The occurrence of injuries in the workplace is not a simple linear association, but rather it is a complex event. The concept of Human and Organization Performance (HOP) stated that to be human is to make errors, and the role of the organization is critical for preventing or reducing such errors [22]. That is, everyone is willing to perform adequately to meet expectations; however, mistakes cannot be avoided sometimes [23]. Human error is a complex construct which is responsible for a high proportion of mishaps and accidents in complex and dynamic systems [24]. It is defined as "a generic term that encompasses all those occasions in which a sequence of physical or mental activities fail to achieve the desired result and when these failures cannot be attributed to the intervention of some chance" [25].

The human errors are fundamentally foreseeable and manageable in many ways [23]. The rate of injuries in ASM operations can be reduced by ascertaining influencing factors that are favorable to error occurrence and by developing means of controls. Komljenovic et al. [23] in his article explained that human error is a symptom of organization failure. As a result, analysis should focus on "why the event happened?" and "why it was not stopped?" From this viewpoint, the role of organization factors such as management/supervision and commitment to safety is critical for preventing error occurrence. ASM operations are run by individuals, families, communities, and occasionally small cooperatives [8]. However, little information exists on how such a management creates conditions for accidents and consequential injuries.

Management commitment to safety refers to "workers' perceptions of the degree to which their managers value and support safe working and are dedicated to workers' safety" [26]. The workers' safety behavior and risk of accidents and associated illnesses and injuries is a leading indicator of the level of management commitment to safety [27]. Workers that have a positive attitude toward their organization tend to be in compliance to their company's safety policies are more inclined to have safe work performance [28,29]. Social support and being valued generate a sense of accomplishment, which then resulted in progressive outcomes [30]. Contrastingly, workers that are dissatisfied with their organization developed a negative attitude toward safety which resultantly increased the likelihood of being exposed to hazards and developing injuries [28,29]. Steenkamp and Van Schoor [31] stated that occupational health and safety is a complex problem for management, and as a result, it must be prioritized.

This study aimed to investigate the risk factors for single and multiple recordable injury events among the mine workers. Recordable injuries are occupational injuries that have resulted in lost workdays. The research study also evaluates miners' perceptions with regard to their mine management commitment to safety. The findings will help the government and nongovernmental organization to develop targeted policies that will reduce, or prevent, recurrence of injuries in ASM operations. Furthermore, it will enhance understanding that poor health and safety in ASM operation is attributed not only to personal characteristics but also to organization commitment to safety.

The first aim was informed by a recent comprehensive analysis of risk factors for recordable injuries in artisanal and small-scale gold mining operation by Ajith and Ghosh et al. [13]. The authors found that likelihood of recordable injury was predicted by age, gender, mining experience, long shift hours, and drug usage, as well as poor working conditions, poor management and supervision, job dissatisfaction, and job stress. However, these authors failed to explain whether these risk factors made miners susceptible to a single-injury event or to multiple-injury incidents. Therefore, these risk factors and other factors such as marital status, education level, and alcohol consumption were evaluated to determine whether they were responsible for single or multiple injuries. Single injury referred to an incident where the miner (s) had experienced a one-time injury which resulted in lost workdays, whereas multiple injuries implied that the miner had suffered more than one injury event during his working time in this mining industry. Mine workers are often transient workers; so this definition provides an industry injury frequency experience record.

The second aim was informed by the HOP concept developed by Komljenovic et al. [23]. In his article, the author established HOP as a complex system because a linear approach cannot deliver a full picture of accident or injuries' underlying causes. According to this concept, workplace accidents causes can be divided into direct ("why the event occurred?") and fundamental causes ("why the event was not prevented?").

2. Materials and methods

2.1. Study area

This study was implemented in Osiri artisanal and small-scale gold mining operation in Migori County, situated in western Kenya, neighboring Lake Victoria to the west and the Republic of Tanzania to the south [13]. Traditionally, the mine was referred to as Malcader. However, in recent times, it has been popularly known as Osiri or Karibu.

2.2. Sample procedure

The study population encompassed 610 miners, of which about 192 mine workers were injured. Using Kothari's [32] formula for sample size calculation, a representative sample of 236 participants was calculated as shown in step 1–3. Thereafter, this population was further partitioned into 162 uninjured and 74 injured participants as presented in step 3 for better representation [13]. In the recent work of Ajith and Ghosh [13], sample determination steps were followed as shown in the following:

Firstly, we calculated the population based on Z values, sample proportion, and confidence level.

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

- 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%)

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

To decrease the sampling error, we corrected the finite population produced in Eq. 1, where N = number of mine workers (both injured and uninjured) and SS = representative sample size.

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

Applying Eq. 2, the representative sample for 610 miners is shown as follows:

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

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

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

where, SS = sample size determined in Eq. 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 are shown as follows:

$$\textbf{Injured mineworkers}\ (y_1) = 236 * \left(\frac{192}{610}\right) = 74$$

$$\textbf{Uninjured mineworkers}\ (y_2) = 236 * \left(\frac{418}{610}\right) = 162$$

The inclusion criteria included mine workers that were older than 18 years who provided freely given consent for participation. Exclusion criteria included were as follows: supervisors and management and local government officials.

During the consultation meetings, the research team registered all the willing mine workers with pseudonym names and asked each miner to remember their identifier. In the registering process, the participants were asked to identify whether they have experienced lost time injuries or not. This information was attached to the participant identifier. The research team then reorganized the pseudonym identifiers and formed a separate list for the injured group and uninjured group. During the survey, each representative sample size was systematically selected from the list of pseudonyms for each group. To do this, the researcher initially identified a random pseudonym from each group to begin with, who was then issued with the necessary research documents. Subsequently, the next identifiers to be surveyed were chosen systematically until the target sample of 162 uninjured and 74 injured participants were achieved in each group.

2.3. Instrument and procedures

A multiitem structured closed-ended questionnaire was developed from relevant published literature. The questionnaire was divided into four sections. In the first section, participants were asked about their age group, gender, marital status, education level, years of experience, and hours worked per week. The second portion of questionnaire asked participants about substance usage (that is, alcohol and drugs); specifically, we asked whether they have ever tried substances, about their frequency of coming to work just after consumption, about their frequency of coming to work with hangover, about their frequency of consumption while working, about near misses due to substances, about accident due to substances, and about getting injured or injuring someone because of substance use. The substance usage questions were adopted from Alcohol Use Disorders Identification Test and Alcohol, Smoking, and Substance Involvement Screening Test which were developed by the World Health Organization and some from the study by Pidd et al. [33].

In the third section, we questioned participants about the working conditions, management and supervision, job dissatisfaction, and job stress, which included five constructs of assessing occupational safety developed by Hayes et al. [34]. This construct assessed management safety practices, supervisor safety, coworker safety, and job safety and satisfaction with the safety program This research study was complemented by a number of other publications [9,21,35–37]. A section of the questionnaire asked injured miners about their nature of injuries, lost workdays, and number of times they have being injured.

The reliability and validity of the instrument was measured before implementation of the research [38]. Cronbach's alpha calculated from pilot testing data was 0.786 which is higher than an absolute minimum of 0.7 [39], indicating that the instrument developed was reliable. To ensure validity, a public health expert was consulted to review the questionnaire and provide feedback. The expert concluded that the research included the necessary information for this specific study.

Before data collection, the participants were contacted through word of mouth from their workers' representatives and mine owners. Flyers were also emailed out to these individuals so that they could distribute and post the rest to other mines in close proximity to their mine site. Upon the arrival of the researcher in Migori County, two research aides, who were familiar with the native language and skilled in public health data collection, were recruited. The researcher then trained these individuals on the use of the research instrument and the ethical conduct of this research. Subsequently, consultation and sensitization meetings were carried out by the research team with the relevant authorities and miners. During the session with miners, the research team provided detailed information about the research instruments and informed consent forms, in addition to registering all willing participants.

During the data collection process, the participants were asked to sit in a group of uninjured and injured miners, following which a random pseudonym was selected to start with in each group, who were then issued a survey to complete. The subsequent names were systematically selected to fill in the questionnaire, during which the literate respondents were allowed to self-administer the survey, while semiliterate or illiterate participants were administered the questionnaire by a research team member in their preferred languages (i.e., English, Kiswahili, and Luo). The completed questionnaires were then collected personally by the researcher. This provided the opportunity to review while maintaining privacy and confidentiality. Each questionnaire took less than 1 hour to complete.

2.4. Data analysis

The questionnaires completed in Kiswahili or Luo language were translated back to English for consistency of the response language. The cleaning and analysis of the survey results were conducted in SPSS software, version 25. The individual characteristics such as age, gender, marital status, and level of education and mining experiences were coded as shown in Table 2. Then, behavioral factors and job-related factors were coded.

Although alcohol and drug (i.e., marijuana, opium and so on.) were assessed with several questions, the objective was to find high-risk users, low-risk users, and not users. Those who did not take substances at all were grouped as "not a user", while those who consumed but did not come to work intoxicated or did not take substances at work were categorized as "low-risk users" and lastly, individuals who came to work intoxicated, consumed substances at work, were involved in an accident, near misses or got injured because of substances were coded as "high-risk users".

For the job-related risk factors which were assessed using a 5 point Likert scale, coding was carried twice depending on the aim of interest. For the evaluation of mine workers' perception of mine management safety, each item under individual risk factors was coded as strongly agree, agree, neutral, disagree, and strongly disagree.

However, for the purpose of the logistic regression analysis, responses to statements under variables were added and assigned an overall category depending on the mean. During the review and coding process, it was found that responses to strongly agree, neutral, and strongly disagree were significantly lower. As a result, strongly agree responses were merged into agree, while neutral and strongly disagree were collapsed into disagree. This combination was dictated by the number of events per variable. That is, in logistic regression analysis, the events per variable must be > 20 to avoid model instability [40,41]. However, the widely recognized rule of the thumb is 10 per variable.

After coding, the survey data were subjected to descriptive statistics, whereby a Chi-square ($\chi 2$) test was performed to determine the factors association with the number of sustained recordable injuries as shown in Table 2. This response variable was coded into three levels: (i) single injury, (ii) multiple injuries, and (iii) no injury. The risk factors from $\chi 2$ analysis that had $p < 0.05$ were considered to influence the number of sustained injuries. To evaluate which categories of risk factors were significant, further analysis was conducted using multinomial logistic regression analysis. The multinomial logistic regression model is an extension of the binary logistic regression model and is used essentially when the response variable demonstrates more than two discrete and unordered categories with nominal properties and multinomial distribution [42]. The bivariate and multivariate (binary) logistic regression model with the considered variables has been explained in the following sections with respect to amount of time spent on the job (experience).

In our study, we have captured and analyzed the mining experience against the number of injuries sustained. Participants were asked to cite how many years they have worked in ASM. The continuous variable experience is then converted to categorical variable. For analysis, the participants' responses were categorized into less than 3 years and more than 3 years mining experiences and then subjected to multivariate (binary) logistic regression. Experience was coded in this way because few miners cited 1 year experience and more with 2 years' experience. Similarly, most miners cited 4 years but not 5 years and over 5 years mining experience. Therefore, it was necessary to find the mean of years worked, which was 3 years of mining experience. Thus, we coded the experience as mentioned. How the amount of time one spends on the job (experience) has been adjusted in the crude odds ratio (COR) and adjusted odds ratio (AOR) is mentioned in following sections.

2.5. Crude odds ratio

In bivariate analysis, COR is calculated by normalizing the injuries with respect to experience (number of years worked in the mine).

	Injury	No Injury	Total Exposure
Less Experienced	a	b	A+ b
More Experienced	c	d	c + d

Odds (for less experienced) = a/(a+b) ≈ a/b ['a' being very small compared to 'b', a+b ≈ b].

Odds (for more experienced) = c/(c + d) ≈ c/d ['c' being very small compared to 'd', c + d ≈ d].

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2.5.1. In bivariate analysis

$$\text{Crude Odds Ratio (COR)} = \frac{a/b}{c/d} = \frac{ad}{bc}$$

COR may give the misleading result, as the influence of other variables is not adjusted. In multivariate (binary) logistic regression analysis, the influence of all variables is adjusted and it gives the AOR.

Multivariate (binary) logistic regression analysis is an extension of bivariate (i.e., simple) regression in which two or more independent variables (Xi) are taken into consideration simultaneously to predict a value of a dependent variable (Y) for each subject and gives AOR.

If x_{gend}, x_{mari}, x_{exp}, x_{drug}, x_{shift}, x_{pwc}, x_{pms}, x_{jds}, and x_{js} represent the risk factors gender, marital status, experience, drug usage, shift, poor working condition, poor management and supervision, job dissatisfaction, and job stress (independent variables), respectively, and y is a binomial outcome variable with p = probability of injury, then the multivariate (binary) logistic regression model is given as follows:

$$\text{logit}(p) = \ln\left[\frac{p}{1-p}\right]$$
$$= \beta_0 + \beta_{gend}x_{gend} + \beta_{mari}x_{mari}. + \beta_{exp}x_{exp}. + \ldots + \beta_{rt}x_{rt} + \ldots\ldots\ldots\ldots + \beta_{sp}x_{sp}$$

$\ln\left[\frac{p}{1-p}\right]$ is called the logistic transformation and it is used as the dependent variable. The term $\left[\frac{p}{1-p}\right]$ is known as the odds of risk.

2.5.2. Adjusted odds ratio

Let us consider two individuals with different values for emotional stability (coded as '1' which represents less experienced and '0' which represents more experienced) and the same values for all other variables in a multivariate (binary) logistic regression model which are shown in the following table.

Individual	Risk factors							
	Gend	Mari	Exp	—	pms	—	—	jst
A	x_{gend}	x_{mari}	1	—	x_{mari}	—	—	x_{jst}
B	x_{gend}	x_{mari}	0	—	x_{mari}	—	—	x_{jst}

In this case, the multivariate (binary) logistic regression equations will be as follows:

For individual A:

$$\ln\left[\frac{p_A}{1-p_A}\right] = \beta_0 + \beta_{gend}x_{gend} + \beta_{mari}x_{mari}. + \beta_{exp}(1). + \ldots + \beta_{rt}x_{rt} + \ldots\ldots\ldots\ldots + \beta_{sp}\cdot x_{sp}$$

For individual B:

$$\ln\left[\frac{p_B}{1-p_B}\right] = \beta_0 + \beta_{gend}x_{gend} + \beta_{mari}x_{mari}. + \beta_{exp}(0). + \ldots + \beta_{rt}x_{rt} + \ldots\ldots\ldots\ldots + \beta_{sp}x_{sp}$$

Subtracting 2nd equation from 1st, we obtain

Table 1
Goodness of fit

Chi-square statistics	Chi-square	df	Sig.
Pearson	333.439	338	0.560
Deviance	239.04	338	1.000

Pearson $p > 0.05$ indicates that the model fitted the data adequately.
df, degree of freedom; sig., significance level.

$$\ln\left[\frac{p_A}{1-p_A}\right] - \ln\left[\frac{p_B}{1-p_B}\right] = \beta_{exp}$$

$$\ln\left[\frac{p_A/(1-p_A)}{p_B/(1-p_B)}\right] = \beta_{exp}$$

$$\left[\frac{p_A/(1-p_A)}{p_B/(1-p_B)}\right] = e^{\beta_{exp}} \quad i.e.\ \frac{Odds_A}{Odds_B} = e^{\beta_{exp}}$$
$$\text{AdjustedOdds Ratio(AOR)} = e^{\beta_{exp}}$$

During the analysis, all the risk factors with $p < 0.05$ were examined first. Next included were other factors with $p < 0.1$ to explore their effects. Some of risk factors were manually removed until the model achieved ideal "goodness of fit" shown in Table 1. The risk factors that returned $p < 0.05$ were considered as a predictor of either single injury or multiple injuries, and their CORs and AORs at 95% confidence interval were noted. The CORs were generated by testing one risk factor against the number of injuries sustained and AOR by inputting several risk factors in the model.

To understand the miners' perception about the management commitment to safety and subsequently organizational safety performance of ASM operation, the participants' responses to items measuring poor working conditions and poor management/supervision were subjected to descriptive statistics. The means and standard deviations as shown in Tables 6 and 7 were generated to measure the safety performance and the level of safety culture.

3. Results

3.1. Model goodness-of-fit test

The MRL goodness-of-fit test was evaluated using the Person's Chi-square ($\chi 2$) test. This test is determined by the model significance level. If the p-value (significance level) is more than 0.05, the study can conclude that the model adequately fits the data; however, if the p-value is less than 0.05, then the model does not fit the data. In this article, the Person's Chi-square p-value was >0.05 as shown in Table 1; therefore, showing that our model sufficiently fitted the data.

3.2. Risk factors and the Chi-square test

Table 2 presents the $\chi 2$ test of risk factors which was an initial test to assess which risk factors predict the number of sustained injuries. The results showed in the following order of significance that poor work conditions ($p = 0.001$), drug usage ($p = 0.001$), shift hours ($p = 0.002$), poor management and supervision ($p = 0.019$), job dissatisfaction ($p = 0.027$), and age group ($p = 0.037$) all had a value of $p < 0.05$ and therefore influenced the risk of either a single-injury event or multiple-injury events.

3.3. Frequency of injuries and lost workdays

Table 3 shows that most injured miners had suffered one injury incidence, which resulted in a significant number of lost workdays compared with those who had experienced two, three, and four incidences.

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Table 2
Participants response to the number of injuries sustained (N = 236)

Risk factors	Multiple injuries	Single injury	No injury	Chi-square (p)
Age groups				**0.037**
1 = 18-34	18 (13.3%)	33 (24.4%)	84 (62.2%)	
2=>35	6 (5.9%)	17 (16.8%)	78 (77.2%)	
Gender				**0.064**
1 = male	15 (11.2%)	35 (26.1%)	84 (62.7%)	
2 = female	9 (8.8%)	15 (14.7%)	78 (76.5%)	
Marital status				**0.085**
1 = single	16 (15.0%)	22 (20.6%)	69 (64.5%)	
2 = married	8 (6.2%)	28 (21.7%)	93 (72.1%)	
Level of education				**0.069**
1 = low (<year 8)	19 (12.3%)	37 (24.0%)	98 (63.6%)	
2 = high (>year 8)	5 (6.1%)	13 (15.9%)	78.0 (56.3%)	
Mining experiences				**0.069**
1 = less than 3 years	17 (12.1%)	35 (25.0%)	88 (62.9%)	
2 = more than 3 years	7 (7.3%)	15 (15.6%)	74 (77.1%)	
Shift hours				**0.002**
1 = more than 8hrs/day	14 (11.5%)	36 (29.5%)	72 (59.0%)	
2 = less than 8hrs/day	10 (8.8%)	14 (12.3%)	90 (78.9%)	
Alcohol consumption				**0.710**
1 = high-risk user	14 (10.4%)	26 (19.4%)	94 (70.1%)	
2 = low-risk user	8 (12.7%)	14 (22.2%)	41 (65.1%)	
3 = not alcohol user	2 (5.1%)	10 (25.6%)	27 (69.2%)	
Drug usage				**0.001**
1 = high-risk user	9 (12.3%)	25 (34.2%)	39 (53.4%)	
2 = low-risk user	3 (3.7%)	14 (17.1%)	65 (79.3%)	
3 = not drug user	12 (14.8%)	11 (13.6%)	58 (71.6%)	
Poor work condition				**0.001**
1 = agree	15 (10.2%)	42 (28.6%)	90 (61.9%)	
2 = disagree	9 (10.1%)	8 (9.0%)	72 (80.9%)	
Poor management and supervision				**0.019**
1 = agree	17 (9.7%)	45 (25.6%)	114 (64.8%)	
2 = disagree	7 (11.7%)	5 (8.3%)	48 (80.0%)	
Job dissatisfaction				**0.027**
1 = agree	20 (12.7%)	38 (24.2%)	99 (63.1%)	
2 = disagree	4 (5.1%)	12 (15.2%)	63 (79.7%)	
Job stress				**0.069**
1 = agree	21 (10.8%)	46 (23.7%)	127 (65.5%)	
1 = disagree	3 (7.1%)	4 (9.5%)	35 (83.3%)	

P < 0.05 represents positive relationship between risk factor and single injury, as well as multiple injuries, while p-value > 0.05 represents negative association.

3.4. Multinomial logistic regression results

Table 4 presents the results of multinomial logistic regression analysis to observe the risk of single injury and multiple injuries with no injury as the reference category. The risk factors identified in Table 3 with $p < 0.1$ were included in the model. The results showed that no single factor was statistically associated with multiple injuries. However, compared with single injury, the research found that all risk factors except age group and job dissatisfaction were contributors ($p < 0.05$).

Table 3
Cross tabulation of the number of times miners have been injured and lost workdays (n = 236 participants)

Number of injury incidences	Lost workdays (indicated severity)					
	No injury	1–6 days	7–13 days	14–29 days	30 days and over	Total
No injury	162	0	0	0	0	162
One time	0	10	5	9	26	50
Two times	0	2	4	2	5	13
Three times	0	1	2	4	1	8
Four times	0	1	0	1	1	3
Total	162	14	11	16	33	236

3.5. Type of injuries

Table 5 shows most miners suffered from laceration injuries and contusion injuries, with facial and burn injuries being the least occurring.

3.6. Mine management commitment to safety

3.6.1. Miners' perception of work conditions

The study aimed to analyze the respondents' working conditions at the mines. As evidenced in Table 6, respondents concurred that their poor working conditions were to a reasonable extent, as revealed by an average score of 3.40; meanwhile, they agreed that lack of personal protective equipment (PPE) was to a moderate extent, which is demonstrated by a mean score of 3.50. Respondents also agreed that they often faced risk of injury on account of performing physical demanding tasks at the mine to a moderate degree, as revealed by a mean score of 3.41. Respondents also agreed that lack of health and safety training put them at high risk of injuries, as revealed by a mean score of 3.54 in both the injured and uninjured category.

Respondents agreed that they often faced risk of injuries because they always worked in awkward positions, as evidenced by a mean score of 3.47; they agreed that lack of identification mechanisms and risk control measures for hazards in this mine site exposed them to injuries, as revealed by a mean score of 3.42. Meanwhile respondents concurred that constant bending/twisting exposed them to injuries, as evidenced by a mean score of 3.23. Finally, they agreed that they often faced risks of injury because their tasks were always repetitive, as indicated by a mean score of 3.21.

3.6.2. Miners' perception about management and supervision

Table 7 illustrates the findings on management and supervision of respondents. According to the findings, respondents agreed to management and supervision in the mines, which was demonstrated by an average score of 3.53. Respondents agreed that workers interest was to a reasonable extent, as revealed by a mean score of 3.56. They agreed that good job performance was to a reasonable degree, as indicated by a mean score of 3.52. Respondents also agreed that honesty and dignity was occurring to a reasonable degree, as shown by a mean score of 3.51. Respondents agreed that workers' suggestions were acted upon to a reasonable degree, as shown by a mean score of 3.53. They also agreed that employers demonstrated care to a reasonable degree, as evidenced by a mean score of 3.56. Finally, respondents agreed that flexibility at workplace was to a reasonable degree, as shown by a mean score of 3.47.

4. Discussion

This study was aimed at investigating why some of the employees working in the same environment as other employees suffered a single-injury event while other employees experience multiple-injury events. The study also evaluated the commitment of mine management to safety in Migori County of Kenya. In the first analysis of risk factors for the number of injuries sustained using multinomial logistic regression, we found that most participating mine workers had suffered a single-injury incident. This finding is similar to the research results of Calys-Tagoe et al. [36]

Table 4
Association of risk factors with single injury and multiple injuries keeping no injury as reference category

Risk factors	Single injury vs no injury			Multiple injuries vs no injury		
	COR (95% CI)	AOR (95% CI)	p	COR (95% CI)	AOR (95% CI)	p
Gender						
Male	2.17 (1.1 − 4.27)	2.55 (1.16 − 5.58)	0.020	1.54 (0.64 − 3.74)	1.70 (0.65 − 4.42)	0.280
Female [RC]						
Marital status						
Single	1.06 (0.56−2.00)	0.80 (0.37−1.72)	0.560	2.70 (1.09 − 6.66)	2.65 (1.02 − 6.91)	0.047
Married [RC]						
Experience						
Less than 3 years	1.96 (1.00 − 3.87)	2.43 (1.09 − 5.44)	0.031	2.04 (0.80 − 5.19)	2.42 (0.90 − 6.50)	0.080
More than 3 years [RC]						
Drug usage						
High-risk users	3.38 (1.45 − 7.65)	4.39 (1.71− 11.27)	0.002	1.11 (0.43 − 2.90)	1.23 (0.44 − 3.44)	0.698
Low-risk users	1.14 (0.48 − 2.70)	0.94 (0.35 − 2.51)	0.901	0.22 (0.06 − 0.83)	0.36 (0.10 − 1.25)	0.038
No users [RC]						
Shift hours						
More than 8hrs/day	3.21 (1.61 − 6.41)	3.33 (1.50 − 7.25)	0.003	1.75 (0.73 − 4.17)	1.80 (0.71 − 5.54)	0.216
Less than 8hrs/day [RC]						
Poor working conditions						
Agree	4.20 (1.86 − 9.51)	3.71 (1.49 − 9.29)	0.005	1.33 (0.55 − 3.22)	1.30 (0.50 − 3.37)	0.594
Disagree [RC]						
Poor management and supervision						
Agree	3.79 (1.41 −10.13)	4.63 (1.56 − 13.73)	0.006	1.02 (0.40 − 2.63)	0.91 (0.32 − 2.61)	0.863
Disagree [RC]						
Job dissatisfaction						
Agree	2.02 (0.98 − 4.15)	2.05 (0.89 − 4.69)	0.090	3.18 (1.04 − 9.74)	3.64 (1.12 − 11.88)	0.032
Disagree [RC]						
Job stress						
Agree	3.17 (1.07 − 9.41)	3.70 (1.07 − 12.83)	0.039	1.93 (0.54 − 6.84)	1.72 (0.45 − 6.64)	0.429
Disagree [RC]						

[RC] represent reference category.
COR, crude odds ratio; AOR, adjusted odds ratio.
$P < 0.05$ represents positive relationship between risk factor and single injury, as well as multiple injuries, while p-value > 0.05 represents negative association. COR represents test association between single risk factor and response variable, whereas AOR represents contributing effect of multiple risk factors with response variable.

where they found that 75 of 95 of severely injured miners experienced only a single injury in the past 10 years. The results of this study can be explained by general awareness and cautiousness of the miners after being injured. In addition, some of personal characteristics, behavioral factors, and job-related factors influenced the number of times participating mine workers got injured as discussed in Section 4.1 and 4.2.

4.1. Predictors for occurrence of multiple injuries

Our results of multinomial logistic regression suggested that marital status, drug usage, and job dissatisfaction were responsible for some miners being injured multiple times. We found that single miners (unmarried) compared with married mine workers have a higher risk ($AOR = 2.65$, $p < 0.05$) of being prone to multiple injuries. Most of the single miners were young people with a limited education background, were less experienced, and had risk-taking behavior. In addition, single miners had less household responsibilities and as a result, tended to work longer hours to continue socializing with friends consequently resulting in fatigue and injuries because of working longer hours. Contrastingly, a study

Table 5
Type of injuries sustained by miners

Type of injuries	Percentage (%)
Contusion	17.16
Laceration	28.40
Wound	11.83
Fracture	15.38
Musculoskeletal pain	14.20
Dislocation	5.92
Amputation	5.33
Burn	1.18
Facial	0.59

Table 6
Miners' perception with regard to work conditions

	Mean	Standard deviation
I often faced risk of injury because of doing physical demanding tasks at the mine.	3.41	1.23
I often faced risk of injury because I am always working in an awkward position at the mine	3.47	1.27
I often faced risk of injury because my tasks are always repetitive.	3.21	1.26
Constant bending/twisting exposed me to injuries.	3.23	1.34
Lack of hazards identifications mechanism and control measures in this mine site exposed me to injuries	3.42	1.31
Lack of personal protective equipment [43]	3.50	1.37
Lack of health and safety training put me at high risk of injuries.	3.54	1.35
Total	**23.78**	**9.13**
Average	**3.40**	**1.30**

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Table 7
Miners' perception about management and supervision

	Mean	Standard deviation
I am not treated with honesty and dignity in this workplace	3.51	1.13
The management does not consider suggestions from me or other workers	3.53	1.11
The interest of the workers is not protected at this place	3.56	1.18
There is no recognition of good performance at this place	3.52	1.15
My superiors only care about the interest, not for their workers.	3.56	1.20
There is no flexibility of break here at this place	3.47	1.16
Total	**21.16**	**6.92**
Average	**3.53**	**1.15**

carried out in a construction company has found married workers to have high rates of injuries because of the household and financial stress [44].

Surprisingly, this study found that miners that were classified to be low-risk drug users frequently got injured. This is contrasted to previous findings which suggested direct correlation between the high-risk users or those who came to work intoxicated or consumed alcohol at work suffering more injuries [13]. The substance abuse in the ASM operation is a recurrent phenomenon, but the rate of consumption varies amongst miners. The individuals within the low-risk drug usage category consume drugs but not at work. Nevertheless, they might come to work intoxicated which subsequently impairs their work performance resulting in a recurrence of being injured.

The results of the data analysis identified that dissatisfied miners had a higher risk (AOR = 3.64, $p < 0.05$) of experiencing multiple injury causing events than single-injury incident miners. ASM operators engage in mining work as a "necessity" to provide an income and as a result many do not have sense of job fulfillment or enjoy doing mining work. This finding is supported by evidence that lack of accomplishment, lack of resources, lack of personal achievement, lack of good pay, lack of benefits, and unsatisfactory work conditions can increase the level of employee carelessness, absenteeism, tardiness, fatigue, and mental stress, as well as reduce the miner's motivation, which in return can produce an occupational injury [13].

4.2. Predictors for occurrence of a single-injury event

In addition to the reasons mentioned in section 4, most mine workers suffer a single accident incidence because of gender, experience, hours worked, perception about work conditions, perception about management/supervision, and job stress. We found that male gender had a higher risk (AOR = 2.55, $p < 0.05$) of a single-injury incident occurring than the female counterpart. Previous studies have also shown that male miners were more inclined to be injured than female miners [18,45]. The results of this study are explained by the fact that male mine workers worked in underground mines where hazards are prevalent, while females worked in the surface mines with limited risks [13]. Male miners tend to be aware of hazards and become cautious after being injured. As a result the number of multiple injuries is reduced. Although incidences of multiple injuries are limited in this category, underground working conditions need to be improved by frequent monitoring and safety awareness.

We also found that mine workers with less than 3 years work experience had a higher risk of suffering a single-injury event (AOR = 2.43, $p < 0.05$) than those with more than 3 years mining experiences. Although previous studies have not specifically divided occupational injuries into single and multiple injuries, they revealed that less experienced workers are prone to job-related injuries [36,43,46]. The results of this study can be explained by the fact that less experienced miners tend to be not aware of hazards which often lead to a major single incident, but after the single exposure to injury, miners tend to be more aware, focused, and even find means to self-protect.

Further analysis suggested that miners who worked for more than 8 hours per day had a higher risk of experiencing a single-injury incident (AOR = 3.33, $p < 0.05$) compared with those who worked for less than 8 hours per day. Previous studies have demonstrated that working for more than 8 hours increased the risk of fatigue and subsequent loss of concentration among the miners which latter resulted in a single-injury event [45,47]. Most miners were found to work more than 8 hours per day in Migori. Therefore, the present study recommends that miners and mine owners should reduce the number of hours worked per day to 8 hours and that fatigue management plans needed to be instituted by the mine owners and used by miners.

Contrasting to the finding in multiple-injury incidences, we found that the miners classified as high-risk drug users had a higher risk (AOR = 4.39, $p < 0.05$) of experiencing a single-injury incident than "low-risk users" and "non-users". This finding is not surprising given that drug usage reduces judgment, concentration, and alertness, as well as impairs performance [43,48], and if the use was excessive, the risk of getting injured increased significantly.

Similarly, research participants that had a poor perception of working condition had a higher risk (AOR = 3.71, $p < 0.05$) of a single-injury incident occurrence than those who disagreed and recorded that their working conditions were not poor. This result corresponds to work conducted by Ghosh et al. [21], where poor working conditions were found to predict the occurrence of occupational injuries. This research result is explained by there being a high prevalence of hazards with nonexisting control mechanisms when the working conditions are poor. Miners learned through their exposure to incidents which might cause a single-injury incident, but this learning was not necessarily undertaken by miners who experienced multiple-injury incidents. A recommendation based on the finding of this research is that miners need to be educated on work related-hazards, hazard identification, risk assessment, and risk control measures to prevent the likelihood of experiencing an injury.

The study results also suggested that workers who perceived poor management and supervision had a higher risk of a single injury (AOR = 4.63, $p < 0.05$) compared with those who perceived that they experienced good supervision and management at work. Studies have shown that poor leadership produced a bad safety culture with serious health problems [49,50]. To resolve health and safety issues in ASM operation, it is important to have competent and effective front-line management who are trained on health and safety and other leadership skills.

In addition to the other factors this research identified, participants who agreed to having job stress had a higher risk (AOR = 3.70, $p < 0.05$) of experiencing a single-injury incident than those who disagreed and reported not being stressed by their job. Job stress can be caused by a number of problems in ASM operations that include having poor equipment, poor safety, and labor intensiveness work and by having a number of psychosocial problems that lead to stress and subsequent injury. In other industries with improved safety, stress also continued to cause occupational injuries [51,52]. Therefore, several stress management plans have been developed in most countries with well-established work environment safety programs that can be replicated in the ASM operation to protect the miners.

4.3. Mine management safety commitment perspectives

The determination of risk factors for injuries using multinomial logistic regression provided an understanding of what influences single-injury and multiple-injury incidences. However, whether miners suffer single or multiple injuries, it is equally important to evaluate the direct and fundamental causes of injuries beyond linearity test. Our analysis in section 4.2 has shown that poor work condition and poor management influences occurrence of injuries. This part of the discussion focuses on why injuries happened and why they were not prevented. As a HOP model dictated that to be human is to err, and therefore, management and the employer should have ensured that preventative risk control strategies were implemented.

According to the descriptive statistics results, miners agreed with the assertion that physical and ergonomic hazards influenced their risk of injuries. The miners' opinions about the labor intensiveness of ASM activities, dangers of working in awkward positions, repetitive tasks, and bending as well as twisting were found positive. These findings are in consistent with the results of the recently published works, wherein the authors revealed physical and ergonomic hazards as a cause of injuries [13,14]. The present results are explained by the lack of safety measures, including proper risk assessment and means of controls. As compared with large-scale mining operations, such hazards are mitigated by conducting job hazard identification assessments and training. Therefore, it is imperative that tools need to be developed and tailored for risk management in accordance with ASM conditions.

Further analysis of the indicators for poor working conditions revealed that all miners agreed to a lack of hazard identification mechanisms, risk control measures of hazards and PPE, as well as the lack of health and safety training being provided. A corresponding study recently conducted in Ghana revealed that the miners perceived their working conditions to be dangerous, and injuries were attributed to the absence of hazard awareness, training, and PPE absence [16,19]. In the present study, these results can be explained by three key themes that were identified from the interview results, whereby all of the participants reported a lack of health and safety, in addition to no equipment training and a lack of PPE. Mining is routinely undertaken with crude equipment such as hand-held shovels, wheelbarrows, and semimechanical drills. To access the ore, the miners reported entering the underground through a wooden supported shaft, without proper ventilation and lightning. Furthermore, the interviewed miners cited that mine owners or management have never issued them PPE and that their salaries are not sufficient enough to cover the costs of purchasing PPE. As a result, they ignored any safety challenges so that they that could sustain their livelihood, thus exposing themselves to accidents and injuries.

The casual undertaking of ASM operation and resultant consequences are frequently blamed upon miners. However, as evidenced from the large-scale operation, the top and front-line management, in conjunction with government agencies, has a significant influence on the safety of mining operations. If the management does not provide proper frameworks, tools, and adequate leadership, the consequences are almost always catastrophic. For example, in the Upper Big Branch mine in southern West Virginia, a coal mining accident claimed the lives of twenty-nine miners. The United States Nuclear Regulatory Commission [53] reviewed the reasons behind this tragic development and discovered that the mine management had brazenly prioritized production over safety. In addition, the workplace had numerous hazards (poor environmental conditions, poor ventilation, and coal dust), which acted as "catalyst to a resulting series of massive explosions".

The analysis of miners' perceptions toward their mine management and assistances illuminates concerns related to matters of safety. The mean data analysis results of miners' view on whether the management treats them with honesty/dignity, considers suggestions, recognizes good performance, and cares and provides break flexibility were found to be low. Miners perceive management to be ignorant of their well-being and interest, thereby undermining their safety. A recent study conducted by Ajith and Ghosh et al. [14] revealed that safety is "safety not priority" among the mine owners of ASM operations.

All the participants reported that the mine owner or management prioritized production over safety and never discussed any safety issues at the start of a shift. This was because government rules and regulation enshrined in relevant laws are not enforced. Safety issues that occurred in ASM operation are not adequately addressed by the government [4]. In addition, ASM operations are run by an individual, families, communities, as well as cooperatives with limited resources and knowledge to be able to advance the welfare of miners [8]. In large-scale mining operations, the management ensured that everyone, including themselves, complied with health and safety standards [4]. Therefore, reducing negative feelings from the miners and providing a sense of fulfillment subsequently translated into a safe and productive day.

5. Conclusions, limitations, and future research direction

The determination of the risk factors associated with single-injury and multiple-injury events, as well as understanding the organizational safety performance (i.e., role of mine owners or management), will help governmentand nongovernment organizations to develop targeted policies that will reduce, or prevent, reoccurrence of injuries in ASM.

In the first part of analysis, we have shown that most ASM miners in Migori County only became injured once. The research also established that the predictors for a single-injury event were similar to those of multiple-injury events. Only single (unmarried miners), lower-risk drug users, and dissatisfied workers were found to relate to multiple injuries, while single injuries were associated with male gender, less experienced worker, long work hours, high-risk drug users, perception about poor working conditions, perception about poor management/supervision, and job stress. Further analysis using the concept of HOP has shown that mine management is not committed to the well-being and health of miners. Generally, mine workers have a low opinion about the contribution of mine owners toward safety. Therefore, the results of this study have indicated that miners and mine management are required to be trained on safe mining practices. In addition, monitoring and recording of the incidences by the mine owners and government need to be encouraged. Furthermore, means of improving safety culture in the workplace should be put at the forefront of any discussion regarding ASM operations.

This research has a number of limitations. Firstly, the data set used for analysis was collected through self-reporting. Therefore, future research should consider comparing self-reporting results with hospital records. Secondly, our study has only focused on the recordable injuries. As a result, some of the frequent occurring minor injuries were missed. The third noted in this research is the adopted sampling approach, whereby participants were systematically selected after stratification. In this form of sampling, particularly in the injured stratum, each participant was given the number, and during the survey, the first random number (first selected participant) was identified followed by systematic choosing of successive participants. Therefore, biasing the number of miners who have suffered single-injury incidences compared with those who suffered multiple-injury events. Finally, working hours record is not available in the mine being an unorganized sector. As no work no pay system is followed, workers do not miss the job except injury-like emergencies. All workers considered here have faced injuries. So their off days are nullified to some extent. As a result, injury exposure level was not calculated.

The present research recommended future research to consider the mentioned limitation for the evaluation of the mine safety issues in ASM operations. In addition, future research should include an in depth of analysis of motivation biases and cognition biases, as well as debiasing mechanisms. Lastly, the impacts of regulatory/legislative bodies need to be evaluated in context of mine safety and illegality.

Ethics approval

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). The research was implemented in the Osiri gold mines, Migori County of Kenya.

Conflict of interest

The authors declare no conflict of interests for this article.

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Appendix A. Supplementary data

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