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ABSTRACT

BACKGROUND: Artisanal and Small-scale Gold Mining (ASGM) is widely practiced in Ethiopia. Injuries are among the public health concerns in the mining sector. This study aimed to assess the prevalence of nonfatal occupational injuries and associated factors among workers in ASGM in Ethiopia.

METHODS: A cross-sectional study design was employed from April to June 2020. A total of 403 participants were selected with a simple random sampling technique. A structured questionnaire was utilized for the data collection. Descriptive statistics were used to characterize the information and binary logistic regression was applied to test the association. Predictor variables with P-value < .05 with an Odds ratio of 95% CI in multivariable analysis were considered as associated factors.

RESULTS: A total of 403 participants were interviewed with a response rate of 95.5%. The prevalence of nonfatal occupational injury was 25.1% in the past 12 months. About one-third of the injuries, 32 (31.7%), were on the upper extremity and feet, 18 (17.8%). Symptoms of mercury toxicity (AOR: 2.39, 95% CI [1.27-4.52]), 1 to 4 years of work experience (AOR: 4.50, 95% CI [1.57-12.9]), full work shift (AOR: 6.06, 95% CI [1.97-18.7]), and job in the task of mining activities (AOR: 4.83, 95% CI [1.48-15.7]) were associated with the injury.

CONCLUSION: A substantially high prevalence of injuries was observed. Work-related factors were found to be significantly associated with the occurrence of injury. The government body, mining sector, and workers are advised to apply interventions focusing on the improvement of working conditions and safety practices to minimize injury.

KEYWORDS: ASGM, prevalence, injury, workers, mining, associated factors

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Introduction

Mining is the *activity*, *occupation*, and industry concerned with the *extraction* of minerals.[1] Huge numbers of workers are involved in mining.[2] Artisanal small-scale mining (ASM) is mining activity, including gold mining, by an individual, or a small group; more than 70% of ASM activities globally are in the informal sector, with limited use of mechanical tools and a labor-intensive nature.[3,4]

ASM has grown in recent years as mineral prices have risen and earning a living from agriculture and other rural activities have become more challenging.[4] There are approximately 40 million ASM miners across 80 countries globally, and more 9 million ASM operators in 23 African countries, including Ethiopia.[4,5] ASGM is one of ASM with an estimated contribution of 20% of the world's gold product.[4] Despite these significant contributions to major global mineral supply chains, ASGM has many public health challenges. Occupational injuries are a problem among workers in this mining sector.[5]

When compared to large-scale miners, small-scale miners are 6 to 7 times more likely to experience an occupational injury.[6] Due to the informal sector nature of this mining, the absence of safety laws, law enforcement, training, functional infrastructure, and equipment are some of the most widely reported factors that have contributed to an increase in injuries among small-scale miners in most countries.[5,7] Previous studies reported the common causes of injury, among ASGM workers were machinery/tools, falling, explosion, fire, the collapse of mining sites, and rock falling.[8-11]

Occupational injuries are major health concerns in ASGM occupational settings, especially in Africa.[8,12-14] The prevalence of nonfatal occupational injury among ASGM workers varied from 235 to 455 in Ghana[8-11] to 447 in Kenya[13] among 1000 workers. Studies also showed underground work, personal protective equipment, education, an alternative source of income, shift hours, drug usage, gender, and experience as associated factors.[10,13,14]

Gold mining has a long history in Ethiopia, was started in the 1930s in Oddo Shakiso district.[15] The mining sector was taken as a priority area for the achievement of growth and transformation plan II (2016-2020) in the country.[16] The

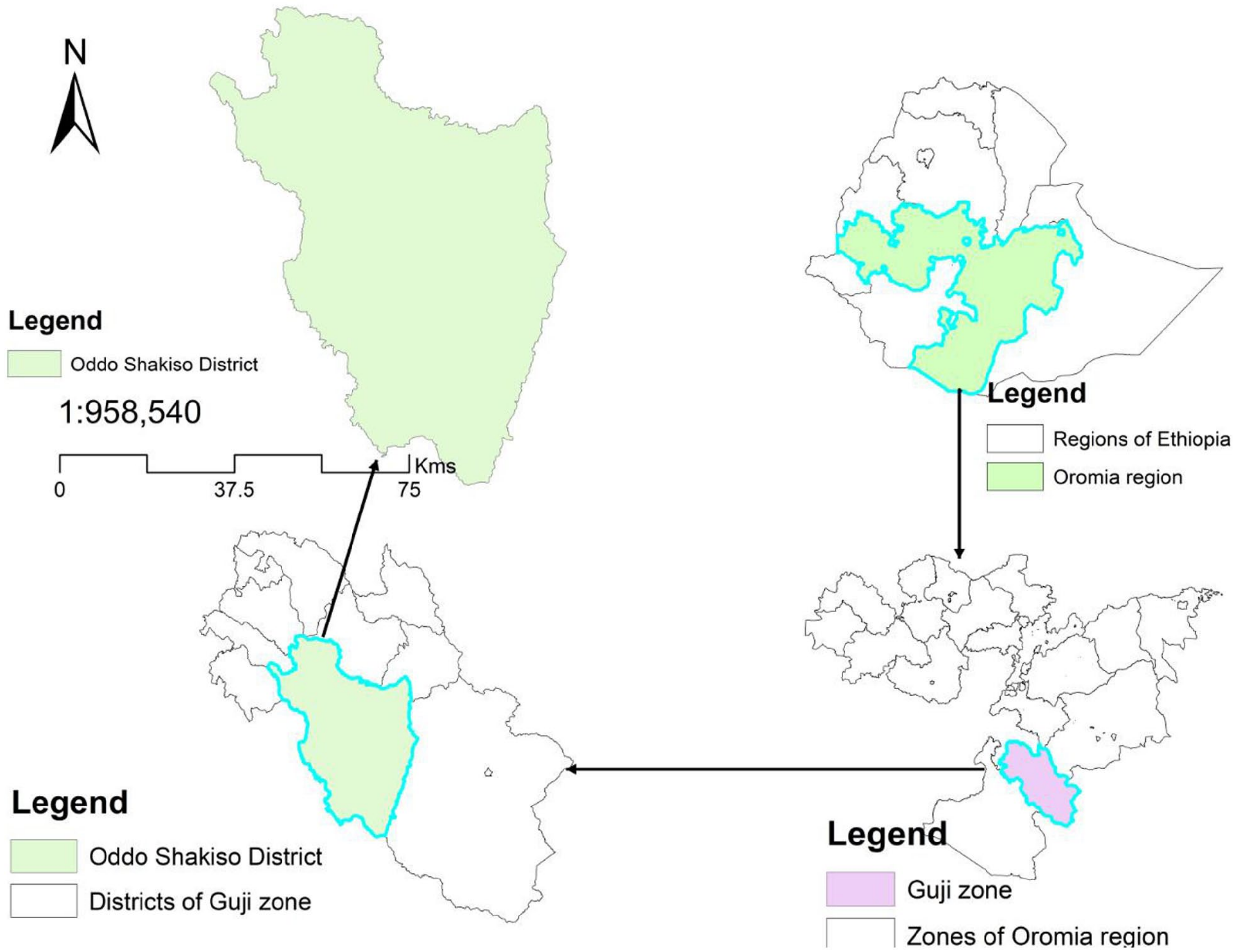

Figure 1. Map of the study area (Oddo Shakiso district).

country has a huge potential for ASGM and more than 450 000 miners are directly involved in ASGM jobs.[4] However, ASGM job is among the most hazardous jobs because of the absence of basic infrastructures and rudimentary tools used in the area.[4,5] Information about injuries among ASGM workers is not adequately addressed in the country.[17] This study aimed to assess the prevalence of injuries and the associated factors among ASGM workers. The findings of this study will contribute on knowledge to prevent occupational injuries and to develop the prevention strategy among ASGM industries in Ethiopian and for international communities.

Methods

Study design and setting

A cross-sectional study design was employed from April to June 2020 in Oddo Shakiso District artisanal and small-scale gold mining sites, Guji Zone, Oromia Regional State, Ethiopia. Oddo Shakiso District is 139 km far away from Negele (the capital of Guji Zone) and 490 km the south of Addis Ababa, the capital city of Ethiopia (Figure 1). The district is organized by 22 rural kebeles (lowest administrative hierarchies), out of which 11 (50%) have ASGM cooperatives. The total population of the district was 132 017 of which 66 537 were males and 65 480 were females. About 14% of the total population practiced ASGM.[15]

Source population

All ASGM workers in the 3 selected kebeles were included in the study with the criteria of an aged ⩾18 years old, residing and working within the district for at least a year. Those miners who were absent at the time of data collection were excluded from the study.

Sample size determination and sampling procedure

There were no similar studies in Ethiopia among ASGM workers. A sample size of 422 was calculated using a single population proportion formula with the maximum sample size assumption of prevalence (P) of 50%, marginal error (d) of 5% and 95% confidence level ($Z\alpha½$ = standard Z score = 1.96, corresponding to 95% confidence level), and 10% added for the nonresponse rate.

$$n = \frac{\left\{(z\alpha / 2)^2 * p\left(1-p\right)\right\}}{d^2}$$

Three kebeles were selected with the lottery method from 11. A total of about 47 ASGM worker cooperatives with an average of 35 members, a total of 1645 workers were reported in the selected Kebeles.[18] The sample size was proportionally allocated to ASGM worker cooperatives. Study participants (*n*) were selected by a simple random sampling method from each mining site of ASGM worker cooperatives.

Data collection

The injury was the dependent variable, whereas sociodemographic characteristics (age, gender, religion, marital status, education level, family size, and average monthly income), nighttime sleeping disorder, a symptom of mercury toxicity, and work-related characteristics (work experience, work shift, tasks, jobs other than mining activities, occupational health and safety training, and the use of personal protective equipment) were the independent variables of the study.

A pretested structured questionnaire was used for data collection. The tool was developed based on previously published occupational injury-related literature.[8,11,12,19] The data collection questionnaire was prepared in English and translated to Afan Oromo (the local language) and back translation was done by the language experts to ensure consistency. The injury types were classified based on the international statistical classification of diseases and related health problems.[20]

Three diploma-holding health professionals handled the interview data collection, a laboratory technician participated in urine sample collection and a supervisor contributed to data collection follow-up. Three days of training were provided for the data collectors about the study objective, the study tools, approach, and ethical issues. A pretest was done among 5% of the sample size in the unselected kebeles. After interviews were conducted, about 20 ML of urine samples were collected in clean plastic bottles for protein analysis. All urine containers were properly coded using the unique number of participants. Safety measures were applied in the collection process of the samples to avoid contamination. Immediately after the sample collection, the urine protein was assessed semi-quantitatively using the dipstick.[21] Data collection activities were carried out with close follow-up by the principal investigator and the supervisor.

Operational definitions

Injury: an incident of work place and participants self-report as cause to miss work for at least a day excluding the day of injury accident.[19,20,22] ***Artisanal and small-scale gold mining***: gold mining conducted by small enterprises/worker cooperatives with limited capital investment and production.[23]

Excavation: extracting gold from the soil by digging underground wells.[23]

Panning: uses water to separate heavy gold particles from other lighter particles within a -medium-sized pan.[24]

Amalgamation: mixing liquid mercury with ore to separate the gold from the other minerals or ore.[23]

Smoke cigarette: a worker who was a regular cigarette smoker at the time of the study.

Drink alcohol: drinking alcohol at least weekly.[25]

The sleeping problem at night: self-reporting of loss sleeping at night

Symptoms of mercury toxicity: worker whose proteinuria (protein in urine) found ⩾0.3 g/l by urine dipstick test)[26] and has at least one of the following mercury toxicity indicators: excessive salivation, tremors at work, sleep problems at night, gingival bluish coloration, ataxia of gait, and leg (heel-shin) ataxia.[27]

Data analysis

The completeness and consistency of the data were checked before data entry. Data was entered into Epi Info version 7.2. Cleaning and analysis were done using SPSS software version 20. Descriptive statistics were used to characterize the data. The association between the variables was assessed by bivariate and multivariate analysis. Binary logistic regression analysis was performed to select candidate variables for multivariable logistic regression analysis. Those explanatory variables having a P-value < .25 in bivariate analysis were used as a cutoff point to reduce the cofounder effect in the multivariable analysis.[28] Finally, variables with $P < .05$ at a 95% confidence level in the multivariate analysis were considered statistically significant. Model fitness and -multicollinearity assumptions were checked. Hosmer–Lemeshow goodness model fitting was $X^2 = 9.2$ with a degree of freedom of 8 and a significance equal to 0.33. The multicollinearity result revealed a variance inflation factor <3 and tolerances >0.4.

Ethics approval and consent to participate

The research was ethically approved by the Addis Ababa University Ethical Review Board. Permission was given from the Ministry of Mine, Oromia Mine Bureau, Oddo Shakiso District Mining Office, and from respective kebele leaders. The participants were asked whether they are volunteers or not to participate in the study. In the data collection process, the interview was conducted only by fully volunteer study participants. Each volunteer participant had an equal chance of being interviewed; there was full right to ask any question, refuse or terminate their participation. Data was coded and kept secret to ensure its confidentiality.

Results

Socio-demographic characteristics

A total of 403 participants were interviewed with a response rate of 95.5%. In this study, 317 (79.0%) of those interviewed were males. The mean (±SD) age of the miners was 30.3 (±7.0) with a range of 18 to 50 years, and the majority of the miners (73.0%) had primary school education. Monthly average income varied from 1000 to 10 000 with a mean (±SD) of 4775.0 (±1764.0) in Ethiopian Birr (ETB) (Table 1).

Table 1. Socio-demographic characteristics of artisanal and small-scale gold mining workers in Oddo Shakiso district, Ethiopia, 2020.

VARIABLE *N* = 403	FREQUENCY	PERCENT
Sex		
Male	317	79.0
Female	86	21.0
Age		
18-29	195	48.4
30-39	161	40.0
40-50	47	11.6
Marital status		
Single	193	48.0
Married	178	44.0
Divorced	32	8.0
Educational status		
Informal education	86	21.3
Primary school	292	72.5
Secondary school and above	25	6.2
Family size		
⩽5	302	75.0
>5	101	25.0
Average monthly income (ETB)		
1000-3500	122	30.0
3501-5000	141	35.0
5001-6000	68	17.0
6001-10 000	72	18.0

Work- related and personal characteristics

The average year (±SD) of work experience was 9 (±6) with the range of 1 to 30. The majority of participants, 261 (64.8%), worked both in the morning and afternoon shifts. More than half of the participants, 221 (54.8%), engaged in excavation, and panning jobs. Out of all miners, 56 (13.9%) had other jobs in addition to mining. All participants did not take any training about occupational health and safety at any time, and nearly all (98.5%) did not use personal protective equipment. Out of the total participants, 128 (31.8%) drink alcohol, 89 (22.1%) smoke cigarettes, and 47 (10.7%) sleeping problems at night. A total of 72 (17.9%) participants had symptoms of mercury toxicity during the study period (Table 2).

Table 2. Work-related and personal characteristics among artisanal and small-scale gold mining workers in Oddo Shakiso district, Ethiopia, 2020.

VARIABLE *N* = 403	FREQUENCY	PERCENT
Experience (in years)		
1-4	100	24.8
5-10	194	48.1
>10	109	27.1
Work shift		
Half shift	53	13.2
Full shift	350	86.8
Tasks (jobs)		
Panning and amalgamation	43	10.7
Excavation and amalgamation	47	11.7
Excavation, panning, and amalgamation	313	77.7
Jobs other than mining		
Yes	56	13.9
No	347	86.1

Prevalence of non-fatal occupational injuries

The prevalence of nonfatal occupational injuries was 25.1% (CI: 21.3%-29.0%) in the past 12 months. About one-third of the injuries, 32 (31.7%), were encountered on the upper extremity, and foot injuries were the second most prevalently affected body part, 18 (17.8%). Among the injured participants, 46 (45.5%), received a first aid/ medical services, and 55 (54.5%) were treated by traditional methods. Abrasion was the leading type of injury with 31 (30.7%), followed by lacerations with 19 (18.8%). The collapse of mining pits, 31 (30.7%), and falling, 29 (28.7%) were the leading mechanisms of injury. More than one-third, 79 (78.2%) of the injuries lets the workers absent from work for more than 5 days (Table 3).

Factors associated with non-fatal occupational injury

Each variable was analyzed using bivariate logistic regression. Variables including age group, marital status, drinking alcohol, symptoms of mercury toxicity, monthly income, work experience task/job, work shift, and having a job other than mining were candidates to multivariate logistic regression analysis. In the multivariate logistic regression analysis, symptoms of mercury toxicity (AOR: 2.39, 95% CI [1.27-4.52]), 1 to 4 years of work experience (AOR: 4.50, 95% CI [1.57-12.9]),

Table 3. Characteristics of nonfatal occupational injuries among participants in artisanal and small-scale gold mining workers in Oddo Shakiso district, Ethiopia, 2020.

VARIABLE	FREQUENCY	PERCENT
Nonfatal injury (n = 403)		
Yes	101	25.1
No	302	74.9
Types of injury (n = 101)		
Abrasion	31	30.7
Lacerations	19	18.8
Punctured wounds	15	14.9
Fracture	10	9.9
Spinal cord injury	9	8.9
Dislocation	6	5.9
Neurogenic shock	4	4
Others	7	6.9
Injury frequency (n = 101)		
Once	85	84.2
Twice or more times	16	15.8
Injured body parts (n = 101)		
Upper extremity	32	31.7
Feet	18	17.8
Lower extremity	13	12.9
Head	13	12.9
Back	12	11.9
Face	7	6.9
Others	6	5.9
Cause of injury (n = 101)		
Collapse of mining pits	31	30.7
Falling	29	28.7
Hit by objects	13	12.9
Assault	10	9.9
Improper use of tools	6	5.9
Fires and explosion	4	4.0
Drowning	3	3.0
Others	5	4.9

involvement in 2 work shifts (AOR: 6.06, 95% CI [1.97-18.7]), and engagement in all tasks in mining activities (AOR: 4.83, 95% CI [1.48-15.7]) were significantly associated with injury at P-value < .05 (Table 4).

Discussion

Occupational injuries are a public health problem for employees worldwide. The injuries are also a major health concern in ASGM occupational settings, especially in Africa.[8,12-14] Previous studies showed underground work, personal protective equipment, education, an alternative source of income, shift hours, drug usage, gender, and experience as associated factors.[10,13,14] The current study revealed the prevalence of occupational injury and associated factors of mercury toxicity and work related conditions. These findings might be important in injury intervention for the society and policy makers.

The prevalence of nonfatal occupational injuries was 25.1% (95% CI: 21.3%-29.0%) in the past 12 months. This finding is in line with similar studies in Ghana (23.5%, 25%, and 28.9%).[9-11] However, it is lower than other studies reported in Kenya (44.7%)[13] and the Democratic Republic of the Congo (72.2%).[29] The reason for the disparity between the current and the previous studies might be the type of mining activities,[29] variation in working population characteristics (in terms of alcohol, drug use, safety culture etc),[13,14,29] and injury definition. A definition of workplace injury can have a big impact on the prevalence estimate. The current study considered "at least 1 day off from work following an injury" as compared with other studies' definitions without considering the days off after the accident.

The most common injury type in the current study was an abrasion, followed by lacerations. It is in line with other studies.[9] Other similar studies reported lacerations as the most common injury type.[8,11,14] The disparity between these studies might be due to the different machines or local tools used for mining, access to safety awareness, and personal protective equipment utilization among mining workers. Among the injured body parts, this study reported the upper extremity as the most affected among the participants. This is consistent with findings in studies on ASGM in Kenya,[13] Ghana,[11] and the Democratic Republic of the Congo.[29] The explanation for the findings might be due to the rudimentary mining methods, poor processing, and the handling activities with hands in these sectors, which might lead to the upper extremities injury.[10,13,30] The most frequently occurring injuries in this report were due to the collapse of the mine pits and falls. It is in line with a similar study in Ghana.[12] It might be possible that one risk factor for injury among ASGM personnel is the reality of underground work or digging without safety operations.[10,31]

Various predicted factors might increase the likelihood of injury occurrence among different studies. Socio-demographic risk factors like sex, education level, age were not significant in the current study. These findings are in line with other studies.[8,10,13] The reason might be due to the nature of the work environment hazards (use of rudimentary tools and the nature of the tasks) and the workers skill on how they perform in a safe way (it is aquried through experience) in the current study.

The current study identified symptoms of mercury toxicity, less years work experience, being involved in 2 work shifts, and

Table 4. Logistic regression analysis result of non fatal occupational injury and associated factors among artisanal and small-scale gold mining workers in Oddo Shakiso district, Ethiopia, 2020.

VARIABLES	INJURY		BIVARIATE ANALYSIS	MULTIVARIATE ANALYSIS
	YES	NO	COR (95% CI)	AOR (95% CI)
Age in years				
<30	57	138	1.54 (0.98-2.42)	1.10 (0.54-2.24)
⩾30	44	164	1.0	1.0
Marital status				
Single	57	136	1.0	1.0
Married	38	140	0.65 (0.40-1.04)	1.13 (0.56-2.26)
Divorced	6	26	0.55 (0.23-1.40)	0.73 (0.24-2.24)
Drink alcohol				
Yes	40	88	1.60 (1.00-2.55)	0.64 (0.38-1.09)
No	61	214	1.0	1.0
Symptoms of mercury toxicity				
Yes	24	48	1.65 (0.95-2.87)	2.39 (1.27-4.52)*
No	77	254	1.0	1.0
Average level of income (in ETB)				
1000-3500	35	87	1.61 (0.91-2.85)	1.29 (0.63-2.61)
3501-5000	38	103	1.48 (0.85-2.58)	1.20 (0.65-2.21)
>5000	28	112	1.0	1.0
Work experience				
1-4	35	65	2.26 (1.20-4.23)*	4.50 (1.57-12.9)*
5-10	45	149	1.78 (1.05-3.03)*	1.46 (0.71-3.03)
>10	21	88	1.0	1.0
Work shift+				
Half shift	4	49	1.0	1.0
Full shift	97	253	4.50 (1.65-13.36)*	6.06 (1.97-18.7)*
Task (job)				
Panning and amalgamation only	4	39	1.0	1.0
Excavation and amalgamation only	9	38	2.31 (0.66-8.14)	2.90 (0.71-11.8)
Panning, excavation an amalgamation	88	225	3.81 (1.32-11.0)*	4.83 (1.48-15.7)*
Having a job other than mining				
Yes	8	48	1.0	1.0
No	93	254	2.20 (1.00-4.81)	1.75 (0.77-3.98)

*Statistically significant at *P*-value < .05; +Half shift includes work in either morning or afternoon; Full shift includes work in the morning and afternoon or work in the afternoon and evening.

being engaged in various tasks of mining such as panning, excavation, and amalgamation jobs that were significantly associated with injury. The study participants with symptoms of mercury toxicity had more than 2 times of likelihood of injury accidents (AOR: 2.39, 95% CI [1.27-4.52]) compared with workers who had no such symptoms. ASGM workers used mercury metal to extract gold from ore through amalgamation. The amalgam is heated to evaporate the mercury and isolate the gold so that workers might expose it to evaporate forming through inhalation.[32] High mercury exposure causes central nervous system abnormalities, which can lead to exhaustion, cognitive impairment,[33,34] and effects on the muscles that lead to muscle weakness.[35] These health problems might contribute to the occurrence of injury.

The current study identified work-related conditions such as years of experience in gold mining, work shifts, and tasks associated with occupational injury. Workers who had 1 to 4 years of experience reported more than 4 odds of injury (AOR: 4.50, 95% CI [1.57-12.9]) than the more experienced workers` group. Other similar studies support this finding that less work experience is a predictor of occupational injury.[11,31,36,37] Because; workers in this sector used rudimentary mining devices and poor processing[10,13,30] and previous work experience might increase the skill to perform the job without injury accident.[36,38] The other reason might be that almost all participants in the current study did not use personal protective equipment and had no history of training in occupational health and safety to prevent injury. So, unexperienced or unskilled workers might be more frequently prone to injuries due to this work condition than the experienced group.[38,39]

Workers involved in full work shifts had an injury likelihood more than 6 times (AOR: 6.06, 95% CI [1.97-18.7]) higher than the half-shift workers in the current study. The full-shift miners engaged in work for an extended hour in a day. The disparity in injury accidents could be attributable to a risk factor for occupational injuries, which is the long work hours each day.[14,37] Also, all participants in the current study practiced gold separation from ore through amalgamation. But workers engaged in both panning and excavation jobs had more than 4 odds of injury (AOR: 4.83, 95% CI [1.48-15.7]) compared with panning workers. The reason for this finding could be that workers who have several jobs are more exhausted and prone to making mistakes; hence, working numerous jobs is linked to an increased risk of injury.[40]

The high participation rate, a standard case definition of injury, and standard assessment instruments were the strengths of this study. However, the majority of the findings were based on the self-reports of participants, and the injury case was not validated clinically. In addition, ASGMs were in informal sectors where temporary employment is a common practice, and severely injured workers may not return to their job during the data collection period or forever, indicating that the true prevalence estimate might be higher.

Conclusion and Recommendations

This study shows that the injury prevalence was substantially higher among ASGM workers in Oddo Shakiso mining sites, Guji Zone, Oromia Regional State, Ethiopia. Symptoms of mercury toxicity, fewer years of work experience, being involved in 2 work shifts, and being engaged in all tasks were significantly associated with injury. Findings suggest that improvement in working conditions and safety practices reduce occupational injuries. Recommendations emphasized eliminating the use of mercury in gold extraction, and training in occupational safety and health, especially on the use of safe work tools and the means to create a safe working environment. The government bodies are recomended on monitoring occupational health and safety in the mining industries. The industries and workers are advised to apply interventions focusing on the improvement of working conditions and safety practices.

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Authors' Contributions

FA was involved in the write-up of the research proposal, supervision of the data collection, data entry, data cleaning, data analysis, and writing of the manuscript. YT, WT, AK, HM, and GK were involved in the write-up of the research proposal, the data analysis, and the writing of the manuscript.

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