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Multiple Risk Exposure and Chronic Obstructive Pulmonary Disease Characteristics among Men in a Mining Community in Northern Tanzania

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Abstract

Background: Chronic obstructive pulmonary disease (COPD) contributes to a substantial burden of diseases globally. The existing unregulated small-scale mining activities in Africa could expose miners to excessive air pollution and the subsequent development of COPD. Understanding the co-existent multiple risk factors for COPD is crucial for local public health action.

Methods: This cross-sectional study was conducted in a small-scale, informal mining site in Tanzania. The eligible participants were active miners, ex-miners and non-miners aged ≥30 years. The participants were assessed for respiratory symptoms and risk factors and underwent testing for spirometry, with COPD defined based on post-bronchodilator (BD) $FEV_1/FVC<70\%$. The air pollution was monitored based on PM_{10} level in mining pits using TSI Side Pak^{TM} AM510 samplers.

Results: 702 men [480 active miners, 170 ex-miners and 52 non-miners] were recruited with a mean age and standard deviation (SD) of 40.95 ± 9.21 years, and two-thirds were cigarette smokers. The prevalence of COPD was estimated to be 15.20%, 17.10% and 15.40% in active miners, ex-miners and non-miners, respectively. Over 18% of current cigarette smokers had significant nicotine dependence, which was associated with the duration of smoking ($p= 0.028$) and the number of pack years ($p = 0.002$). Many COPD patients presented with cough and had frequent exacerbations but with mild to moderate airway limitation. The survey revealed up to 20,000μg/m^3 of PM_{10} in the underground microenvironment, exceedingly higher than the acceptable limits.

Conclusion: The prevalence of COPD among the mining communities is substantial in Tanzania. The patients are largely young, and the majority are cigarette smokers. The mining activities are typically carried out without protective gear, underscoring the critical role of a multi-sectorial approach in preventing COPD.

Keywords: Air pollution, chronic obstructive pulmonary disease, cigarette smoking, mining, spirometry

Background

Chronic obstructive pulmonary disease (COPD) is a significant cause of morbidity and mortality globally, albeit scarce data in sub-Sahara Africa (SSA) (Chan-Yeung, Ait-Khaled, White, Ip, & Tan, 2004; Groenewald *et al.*, 2007; Mehrotra et al., 2009). In 2019, the overall prevalence of COPD in SSA was estimated to be 10.3 million (Alemayohu, Zanolin, Cazzoletti, Nyasulu, & Garcia-Larsen, 2023). Globally, cigarette smoking and occupational exposure to air pollution are well-known risk factors for developing COPD (Becklake, 1989; Boschetto *et al.*, 2006). However, exposure to biomass smoke and traffic pollution has recently been recognized as significant risk factors for developing COPD in low- and middle-income countries (LMICs) (Burki, 2011; Fullerton, Gordon, & Calverley, 2009; Salvi, 2015). In parallel, the current social and economic transitions in SSA characterized by increased urbanization, industrialization and extensive mineral explorations in

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the context of lack of work safety standards is likely to contribute to air pollution and increased risk of developing occupational lung diseases including COPD (Alemayohu *et al.*, 2023).

COPD is characterized by progressive and irreversible airway limitation resulting from chronic airway inflammatory response due to prolonged exposure to air pollutants (Agusti & Hogg, 2019; Nakamura, 2011). COPD is a recent phenomenon in SSA as many patients with the disease are often misdiagnosed (Salvi, 2015). The ageing populations together with increased cigarette smoking habits and the rising trends in air pollution are potential drivers for the continued rise in COPD in developing countries (Agusti & Hogg, 2019; Ngweina Francis Magitta, 2018). Prolonged exposure to inhalational pollutants in specific occupational groups, who often do not use proper protective gear, exposes individuals to an increased risk of developing COPD.

Patients with COPD present with chronic cough and sputum production with or without dyspnoea (Isidro Montes *et al.*, 2004; Koichi Nishimura, 2002). This clinical presentation tends to be ignored by patients until they present late at advanced stages of disease often after developing intolerable dyspnoea (Koichi Nishimura, 2002). Regrettably, due to lack of expertise and diagnostic capacity such as spirometry (Agusti *et al.*, 2023; Mehrotra *et al.*, 2009), patients with COPD are often misdiagnosed for pulmonary tuberculosis, interstitial lung diseases or even heart failure and offered inappropriate treatment (Chan-Yeung, Ait-Khaled, White, Tsang, & Tan, 2004). The current management of COPD requires stepwise administration of bronchodilators and steroids, preferably via the inhalational route during stable states and exacerbation (Agusti *et al.*, 2023). However, due to shortages of expertise and resources, Global Initiative on Chronic Obstructive Lung Diseases (GOLD) guidelines are often not adhered to in routine clinical practice in LMICs (Agusti *et al.*, 2023; Chan-Yeung, Ait-Khaled, White, Tsang *et al.*, 2004).

Currently, there are widespread, unregulated artisanal mining sites in Tanzania. A lack of proper protective gear and weak regulatory authorities with a greater risk of exposure to excessive inhalational pollutants characterize the mining activities. This study is set to determine the burden of COPD in this high-risk population and assess the air quality within the underground microenvironment where mining activities are undertaken. We further sought to provide evidence for advocacy for regulatory policy change to improve occupational mining standards in Tanzania.

Methods

Study design and study area

This cross-sectional descriptive study was conducted in a small-scale hard-rock mining site in Northern Tanzania. The mining site consists of large-scale and small-scale sites operated by large-scale investors and small-scale local miners respectively. The small-scale mining site is organized into 100 mining pits across the site. Besides other minerals, tanzanite is a significant mineral ore extracted from the area. In the current study, we recruited three groups of participants: active miners, ex-miners, and non-miners. The study was preceded by conducting community sensitization meetings at the selected study sites.

Sampling and sample size estimation

A total of 702 men (480 active miners, 170 ex-miners and 52 non-miners) were recruited. Twenty mining pits from the available 100 were randomly selected, from which we recruited a sample size of 480 active miners on a consecutive basis. The number of workers in each mining pit was pre-determined, and all eligible participants were selected. 170 ex-miners and 52 non-miners aged ≥ 30 years were randomly selected and recruited from the local area. All households were visited in the same study population, and eligible ex-miners were identified for interview. Active miners were operationally defined as men who were actively mining during the study and having been in active mining for at least six consecutive months. Ex-miners were men who had engaged in mining activities at the same site for at least six months. Whenever permissible, a comparison group of eligible individuals who reported to have never been involved in the mining activities were recruited.

Fieldwork and data collection

The study collected information about respiratory symptoms, occupation, respiratory diagnoses, co-morbidities, health care utilization, medication use, activity limitation, health status as well as basic demographic data and personal particulars. The participants were assessed for anthropometry together with measurement of blood pressure and pulse. The burden and determinants of COPD were assessed using BOLD protocol (www.boldstudy.org) with slight modification on demographic details and socioeconomic variables. The interviewers administered a set of BOLD validated questionnaires.

The participants underwent spirometry using 3L-syringe daily calibrated NDD EasyOne^{TM} spirometer (www.nddmed.com) which was repeated 15 to 20 minutes after inhalation of 200μg of salbutamol via a spacer. The diagnosis of COPD was made based on a history of exposure to risk factors and the presence of airflow limitation that is not fully reversible, with or without the presence of symptoms (Agusti et al., 2023). A post-bronchodilator (BD) FEV_1/FVC <70% and a post-BD FEV_1 <80% predicted confirmed the presence of airflow limitation that is not fully reversible (Agusti et al., 2023).

Pollution monitoring

The mining pits were monitored for air pollution in the underground microenvironment based on particulate matter with an aerodynamic diameter <10 μm (PM_{10}) using TSI SidePak^{TM} AM510 personal aerosol monitors (www.tsi.com) with a sampling rate of one minute. Two pre-programmed air sampler units were taken into the underground pits by the volunteer mining workers and positioned at two specific positions; the drilling point and at the rear of shaft where the rest of the miners hide during active drilling. The monitors were left at these positions for the up to 8 hours until the mining shift was over and then carried back to the fieldworkers.

Statistical analysis

The statistical analysis was performed using SPSS software version 18 (SPSS Inc., Chicago, IL). All quantitative variables were summarized as mean and standard deviation. Percentages and absolute numbers were used for summarizing continuous and categorical variables. The χ^2 test was used to compare categorical groups. Regression analysis modelling was used to determine the role of presumed independent variables. A p value of less than 0.05 was considered statistically significant.

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RESULTS

Recruitment and flow chart of the study participants

A total of 851 eligible participants were invited to participate in the study. Of these, 752 completed the questionnaire and underwent spirometry. A total of 702 participants had acceptable post-BD spirometry for whom the final analysis was carried out, as highlighted in Figure 1.

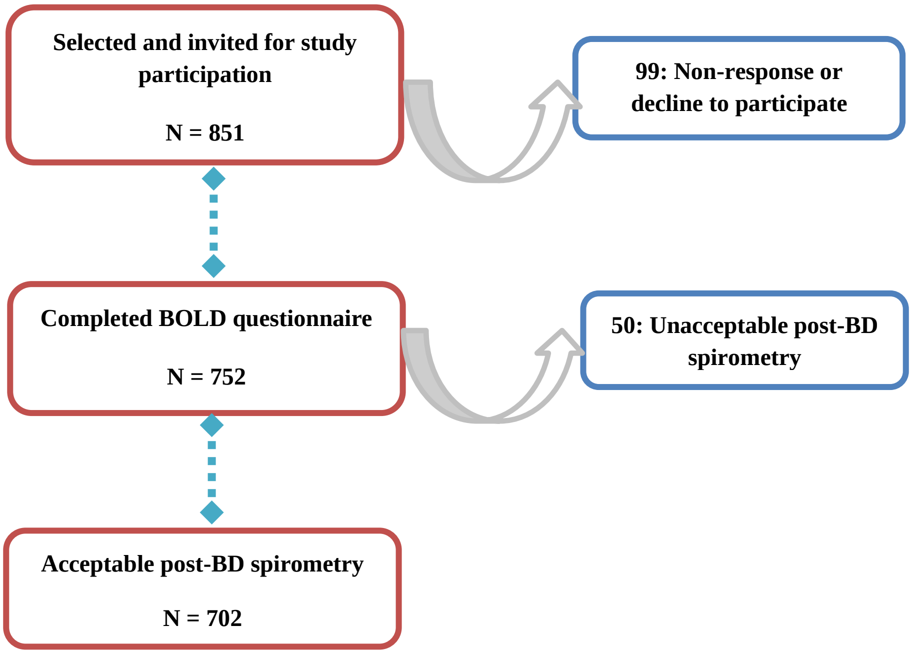

Figure 1: Flow chart for the recruitment of participants from the mining site and the nearby community.

Basic demographic and clinical characteristics of participants who completed BOLD questionnaire and underwent post-BD spirometry

The current COPD survey recruited 702 male participants [(480 active miners; 170 ex-miners and 52 non-miners)], with the mean age ± SD of 40.95 ± 9.21 years. Over 53% of participants were in 31-40 age-group and two-thirds of all participants were either former or current cigarette smokers (Table 1). Eighty eight percent (752 of 851) of all respondents who completed the questionnaires underwent post-BD spirometry. Of these, 75% had received primary education and 73% had good nutritional status. About 68%, 25% and 7% of active miners, ex-miners and non-miners respectively reported either current or former cigarette smoking status (Table 1). Notably, over 40% of active miners were current smokers while about 48% of ex-miners were former cigarette smokers (Table 1).

Table 1: Basic demographic characteristics of responders who completed BOLD questionnaire and post-BD spirometry (N = 702)

Variable		Exposure status			
		Active miners	Ex-miners	Non-miners	Total
Sex	Male	480 (68.40%)	170 (24.20%)	52 (7.40%)	702 (100%)
Age categories	20-30	9 (1.88%)	4 (5.71%)	5 (9.62%)	18 (2.56%)
	30-40	300 (62.50%)	57 (33.53%)	12 (23.08%)	369 (52.56%)
	40-50	132 (27.5%)	56 (32.94%)	15 (28.85%)	203 (28.92%)
	50-60	28 (5.83%)	37 (21.76%)	13 (25.0%)	78 (11.11%)
	60+	12 (2.50%)	15 (8.82%)	7 (13.46%)	34 (4.84%)
Mean age ± SD		36±14.63	45±19.35	48±16.12	40.95+-9.21
Education	Primary	359 (74.70%)	137 (80.60%)	33 (63.50%)	529 (75.30%)
	Secondary	53 (11.10%)	17 (10.00%)	8 (15.40%)	78 (11.10%)
	Others	14 (2.92%)	2 (1.18%)	6 (11.54%)	22 (3.14%)
	No education	52 (10.90%)	14 (8.20%)	5 (9.60%)	71 (10.10%)
	Unknown	2 (0.40%)	0 (0.0%)	0 (0.0%)	2 (0.30%)
Body Mass Index	Underweight	27 (5.70%)	13 (7.70%)	5 (9.60%)	45 (6.50%)
	Normal weight	369 (77.70%)	112 (66.30%)	26 (50.00%)	507 (72.80%)
	Overweight	65 (13.70%)	37 (21.90%)	16 (30.80%)	118 (17.00%)
	Obesity	14 (2.90%)	7 (4.10%)	5 (9.60%)	26 (35.90%)
Smoking status	Non-smokers	163 (34.00%)	45 (26.50%)	28 (53.80%)	236 (33.60%)
	Former smokers	123 (25.60%)	81 (47.60%)	10 (19.20%)	214 (30.50%)
	Current smokers	194 (40.40%)	44 (25.90%)	14 (26.90%)	252 (35.90%)

Prevalence of COPD among exposure groups of study participants based on three diagnostic criteria

The prevalence of COPD based on the criteria of post-BD FEV_1/FVC <70%, was estimated at 15.20%, 17.10% and 15.40% for active miners, ex-miners and non-miners respectively (Table 2). However, the prevalence of COPD varied depending on the criteria used. Irrespective of the exposure category, the overall prevalence of COPD was 15.70%, 11.00% and 20.80% respectively based on post-BD FEV_1/FVC ≤70%, post BD FEV_1/FVC<LLN and post-BD age category criteria (Table 2).

Table 2: Prevalence rates of COPD among three exposure groups based on different diagnostic criteria (N = 702)

Variable	COPD+/-	Mining status			
		Active miners	Ex miners	Non-miners	Total
COPD[1] Post Test Result	Yes	73 (15.21 %)	29 (17.10%)	8 (15.38 %)	110 (15.67 %)
	No	407 (84.79%)	141 (82.94%)	44 (84.62%)	592 (84.33%)
COPD[2]LLN PB Post Test Result	Yes	56 (11.67 %)	17 (10.00%)	4 (7.70%)	77 (10.97 %)
	No	424 (88.33%)	153 (90.00%)	48 (92.31%)	625 (89.03%)
COPD[3] Age Post Test Result	Yes	104 (21.67 %)	35 (20.59 %)	7 (13.46 %)	146 (20.80%)
	No	376 (78.33%)	135 (79.41%)	45 (86.54%)	556 (79.20%)

1: Post-BD $FEV_1/FVC<70\%$; 2: Post-BD $FEV_1/FVC<LLN$; and 3: Age <40 years; Post-BD $FEV_1/FVC<75\%$;

Age (40-60) years; Post-BD $FEV_1/FVC<70\%$ and Age <60 years Post-BD $FEV_1/FVC<65\%$.
The prevalence of COPD generally increased with age in all exposure categories. Intriguingly, ex-miners had the highest prevalence (Table 3). Over 18% of all current cigarette smokers had significant nicotine dependence on the Fagerstrom scale (Table 4). This dependence was significantly associated with the duration of cigarette smoking (p=0.028) and the number of pack years (p=0.002) (Table 5).

Table 3: Prevalence rates of COPD by exposure group and age-categories among respondents (N = 702)

Exposure status	COPD+/-	Age categories					
		≥30	30.1-40	40.1-50	50.1-60	60+	Total
Active miners	Yes	0 (0.00%)	26 (8.70%)	30 (22.70%)	9 (32.10%)	8 (66.70%)	73 (15.20%)
	No	9 (100.00%)	272 (91.30%)	102 (77.30%)	19 (67.90%)	4 (33.30%)	406 (84.80%)
Ex-miners	Yes	0 (0.00%)	3 (5.30%)	12 (21.40%)	8 (21.60%)	5 (33.30%)	28 (16.60%)
	No	4 (100.00%)	54 (94.70%)	44 (78.60%)	29 (78.40%)	10 (66.70%)	141 (83.40%)
Non-miners	Yes	0 (0.00%)	0 (0.00%)	3 (20.00%)	2 (15.40%)	3 (42.90%)	8 (15.40%)
	No	5 (100.00%)	12 (100.00%)	12 (80.00%)	11 (84.60%)	4 (57.10%)	44 (84.60%)

1 Post-BD FEV1/FVC<70%

Cigarette smoking and tobacco dependency among study participants who were current smokers

Table 4: Distribution of Fagarstrom nicotine score scale and nicotine dependence among ever cigarette smokers by mining exposure groups (N = 186)

Variable	Frequency	Exposure status			
		Active miners	Ex-miners	Non-miners	Total
FNS	0	37 (17.31%)	4 (14.81%)	0 (0.00%)	41 (16.67%)
	1	30 (19.23%)	5 (18.52%)	1 (33.33%)	36 (19.35%)
	2	25 (16.03%	2 (7.41%)	0 (0.00%)	27 (14.52%)
	3	24 (15.38%)	4 (14.81%)	0 (0.00%)	28 (15.05%)
	4	24 (15.38%)	6 (22.22%)	0 (0.00%)	30 (16.13%)
	5	12 (7.69%)	4 (14.81%)	1 (33.33%)	17 (9.14%)
	6	8 (5.13%)	0 (0.00%)	1 (33.33%)	9 (4.84%)
	7	2 (1.28%)	1 (3.70%)	0 (0.00%)	3 (1.61%)
	8	4 (2.56%)	1 (3.70%)	0 (0.00%)	5 (2.69%)
	Total	156 (83.87%)	27 (14.52%)	3 (1.61%)	186 (100.00%)
NDS	Low to Moderate Dependency (score 0 to 4)	130 (83.33%)	21 (77.78%)	1 (33.33%)	152 (81.72%)
	Significant Dependency (score ≥5)	26 (16.67%)	6 (22.22%)	2 (66.67%)	34 (18.28%)

FDS – Fagarstrom Dependency Scale; NDS – Nicotine Dependency Score

Table 5: Association between nicotine dependence and selected variables among current cigarette smokers

Variable	NAS	N	Mean	SD	XD	95% LCI	95% UCI	p-value
Age	Low to Moderate	152	39.96	8.21	-2.929	-6.109	0.251	0.071
	Significant Dependence	34	42.89	9.71				
Number of smoking years	Low to Moderate	152	19.28	9.58	-4.113	-7.778	-0.449	**0.028**
	Significant Dependence	34	23.39	10.72				
Number of pack years	Low to Moderate	152	8.33	7.86	-30.742	-72.536	11.052	**0.002**
	Significant Dependence	34	39.08	119.73				

NAS - Nicotine Addiction Scale; SD – Standard Deviation; XD – Mean Deviation; LCI – Lower Confidence Interval; UCI – Upper Confidence Interval

Respiratory symptoms and COPD characteristics among study participants

Moreover, as highlighted in Table 6, it was noted that cough, followed by phlegm were the most common respiratory symptoms presented by patients with COPD irrespective of exposure categories. Moreover, shortness of breath was the least presenting symptom among all exposure categories which was reported by 46.4% of ex-miners and about 25% of both active miners and non-miners. The majority of COPD patients had increased frequency of 3 or more exacerbations within the preceding 12 months which was highest among active miners. The worst mean FEV_1 and FVC parameters were noted among ex-miners and non-miners had the best mean spirometry parameters. Notwithstanding the exposure status, the majority of COPD patients had mild to moderate airway limitation which was reported in 84.9%, 79.2% and 87.5% respectively among active miners, ex-miners and non-miners. Noteworthy, the highest proportion of severe to very severe airway limitation was observed ex-miners and active miners.

Table 6: Respiratory symptoms, exacerbations, spirometry indices and COPD severity based on GOLD classification among all study population

Clinical characteristics	Exposure categories		
	Active miners (n=73)	Ex-miners (n=28)	Non-miners (n=8)
Respiratory symptoms			
Cough	38 (52.1%)	18 (64.2%)	7 (87.5%)
Phlegm	34 (46.6%)	15 (53.6%)	5 (62.5%)
Wheeze	29 (39.7%)	15 (53.6%)	3 (37.5%)
Shortness of breath	17 (25.8%)	13 (46.4 %)	2 (25.0%)
Exacerbation in the past 12 months			
0	3 (12.0%)	3 (23.1%)	0 (0.0%)
1	4 (16.0%)	1 (7.7%)	1 (33.3%)
2	4 (16.0%)	5 (38.5%)	1 (33.3%)
3 or more	14 (56.0%)	4 (30.7%)	1 (33.3%)
Post-test spirometry			
FVC (% predicted)	92.90 ± 19.79	88.73 ± 25.14	104.72 ± 23.07
FEV1 (% predicted)	70.18 ± 18.31	62.98 ± 17.09	78.68 ± 18.85
Severity of airway limitation in GOLD classification			
1 - Mild obstruction	22 (30.1%)	6 (20.7%)	4 (50.0%)
2 - Moderate obstruction	40 (54.8%)	17 (58.6%)	3 (37.5%)
3 - Severe obstruction	10 (13.7%)	4 (13.8%)	1 (12.5%)
4 - Very severe obstruction	1 (1.4%)	2 (6.9%)	0 (0.0%)

Air pollution monitoring in the underground mining pits

The 8-hour measurements of air quality in underground mining microenvironments both at the rear of shaft and drilling points revealed levels of PM_{10} well beyond the acceptable 50μg/m³ World Health Organization (WHO) safety limits (Figures 2, 3, and 4). The average exposure to PM_{10} was revealed to be nearly 5,000μg/m³ while the maximum exposure was beyond 20,000μg/m³ (Figures 3 and 4).

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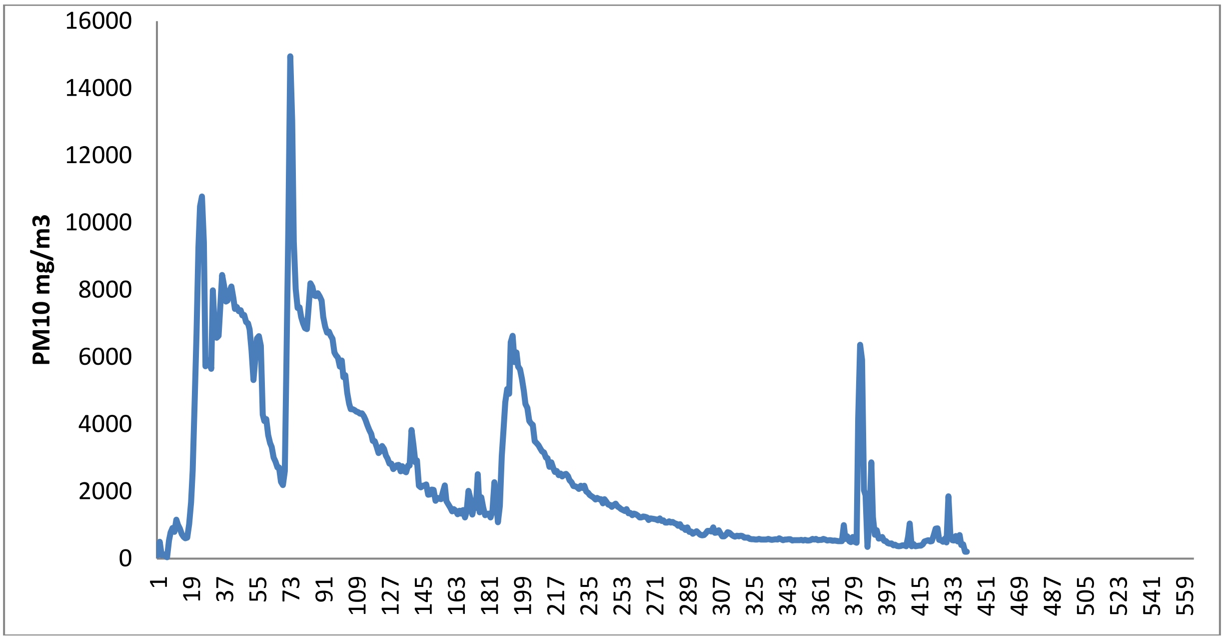

Figure 2: Graphical variation of PM_{10} in a typical 8-hour monitoring session in underground mining pit in a hard-rock mining site

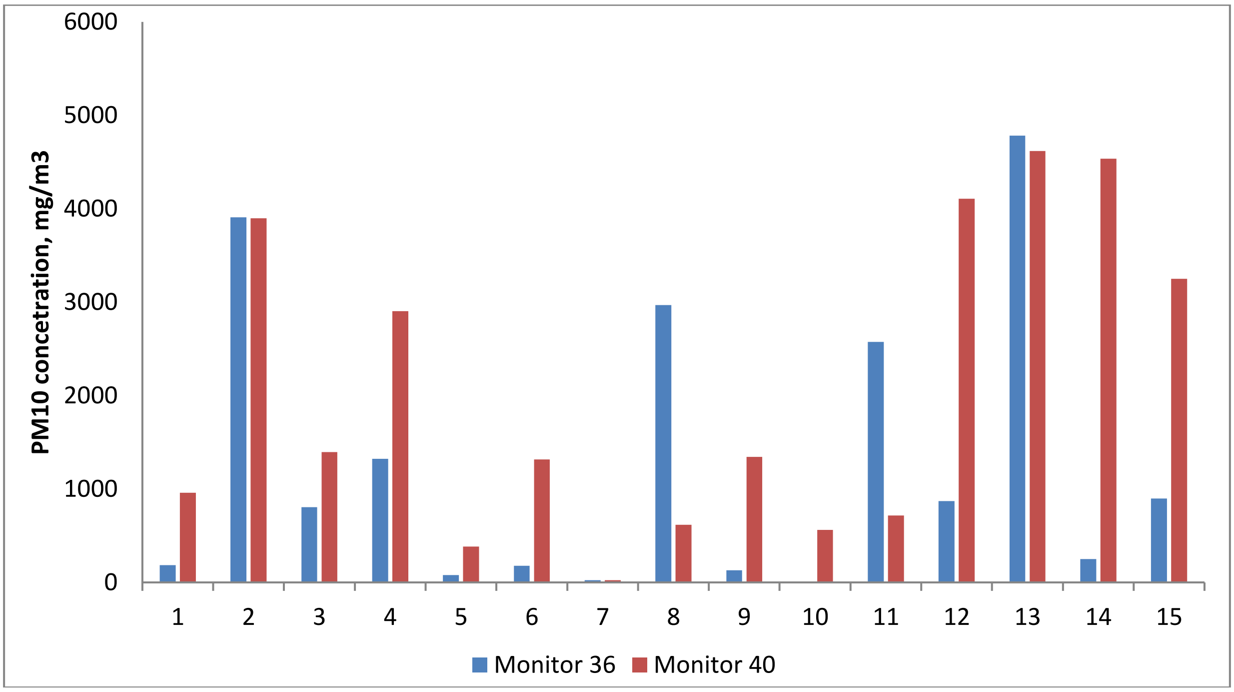

Figure 3: Variation in daily average PM_{10} concentrations for the two monitors situated at the drilling point (monitor serial 40) and rear of shaft (monitor serial 36) in a typical underground microenvironment in 15 selected hard-rock mining pits

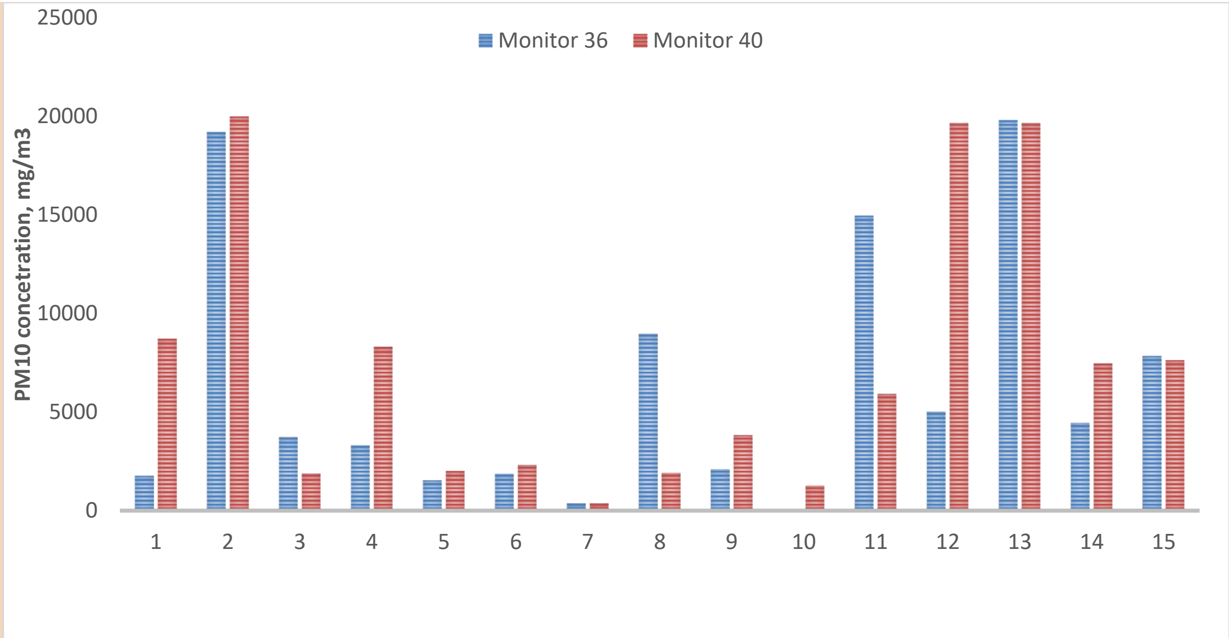

Figure 4: Variation in daily maximum values of PM_{10} concentrations for two monitors situated at the drilling point (monitor serial 40) and rear of shaft (monitor serial 36) in a typical underground microenvironment in 15 selected hard-rock mining pits

DISCUSSION

The prevalence of COPD ranged from 15.20% to 16.60% in the studied mining population in Tanzania similar to the previous reported studies (Balmes *et al.*, 2003; Chan-Yeung, Ait-Khaled, White, Ip *et al.*, 2004). For instance, our results are comparable to reports from community surveys conducted in Uganda and Tanzania which estimated the prevalence of 16.2% and 17.5% respectively (N. F. Magitta *et al.*, 2018; van Gemert *et al.*, 2015). Interestingly, this prevalence did not appear to differ significantly in relation to exposure status in our study. It is possible that individuals who responded as non-miners might have worked intermittently in the mining activities and were thus misclassified as non-exposed. Nearly all study populations irrespective of exposure status were exposed to biomass fuel and up to half of them were ever smokers indicating that other risk factors could have contributed to the development of COPD in this study group.

The current study reported 40% and 48% of active and ex-miners respectively as current and former cigarette smokers. However, a study in Nigeria reported the prevalence of cigarette smoking in a community based study to range from 8.7% in the current smokers to 22% in ever smokers (Adeloye *et al.*, 2015). Likewise, a review by Magitta, NF estimated the prevalence of cigarette smoking among men to be 13.9% in SSA (Ngweina Francis Magitta, 2018). Thus, it is observed that the prevalence of cigarette smoking is exceedingly high among miners compared to the general population.

Moreover, the current study highlights a substantial proportion of all current cigarette smokers to have nicotine dependence based on the Fagarstrom Nicotine Dependency Scale. These individuals are less likely to quit smoking, thus constituting an at-risk population for developing COPD in the absence of purposeful intervention for smoking cessation (Laniado-Laborin, 2009). Given high prevalence of cigarette smoking in this study community, the prevalence of COPD would be expected to be considerably high due to the co-existence of multiple risk factors. One possible explanation would be early retirement of miners upon developing intolerable dyspnoea and emigration from the local population to their place of permanent residence keeping in mind that miners hailed from across Tanzania and nearby countries.

The interplay between cigarette smoking and occupational exposure to pollutants among miners accelerates the deterioration in lung function and subsequent development of COPD (Santo Tomas, 2011). This observation highlights the importance of integrating smoking cessation programs in the overall strategy for prevention of COPD (Liu, Lee, Perez-Padilla, Hudson, & Mannino, 2008; Tonnesen, 2013). Inadvertently, despite efforts made on the implementation of WHO strategy on tobacco control there is a plethora of tobacco adverts and tobacco use still soars in the majority of LMICs (Brathwaite, Addo, Smeeth, & Lock, 2015). Specifically, smoking cessation programs are virtually existent in most countries in SSA. Typically, smoking cessation programs comprises the combination of psychotherapy together with pharmacotherapy, the latter constituting nicotine replacement therapy (NRT) together with specific pharmacological agents (Strassmann *et al.*, 2009; Tonnesen, 2013).

Shortage of skilled healthcare personnel in the psychology and psychiatry could partly hinder such strategies. Besides cigarette smoking, ex-miners were more likely to be older than the active miners, thus age, as a determinant for cumulative risk exposure, could be contributing to their increased COPD risk (Geijer *et al.*, 2006). Further explanation would be the fact that in an unregulated mining industry, people tend to retire from the mining activities when they develop intolerable dyspnea due to undiagnosed COPD. It is thus prudent to suspect that some ex-miners retired from working after developing COPD, thus, contributing to a higher burden of disease among the ex-miners compared to the active miners.

Similar to other studies conducted elsewhere, patients with COPD commonly presented with cough (Isidro Montes *et al.*, 2004). Cough is a recognized predictor of COPD progression while breathlessness or dyspnoea signifies severity of airway limitation (Smith & Woodcock, 2006). In the current study, it was revealed that the majority of ex-miners with COPD presented with dyspnoea which could indicate disease severity probably also associated with inadequate treatment. This observation is in line with other previous studies which reported dyspnoea as a predictor of disease severity (Grosbois *et al.*, 2022; O'Donnell, Milne, James, de Torres, & Neder, 2020). The majority of COPD patients had increased frequency of exacerbations regardless of their exposure status which could indicate inadequate or inappropriate disease management. Moreover, it was observed that ex-miners had the worst mean spirometry parameters including FEV_1, FVC and FEV_1/FVC. However, these poor spirometry results were not reflected in the clinical manifestation and disease severity. Notwithstanding the exposure status, the majority of COPD patients had mild to moderate airway limitation as assessed by GOLD classification. The small proportion of patients with severe COPD in this study could partly be explained by increased mortality of patients with severe disease phenotype.

The 24-hour measurements of air quality in underground mining tunnels and blasting sections revealed excessively high levels of PM_{10}, well beyond WHO acceptable safety limits (WHO, 2021). The miners, who are invariably without protective gear, are constantly exposed to these extreme levels of air pollution (Koong *et al.*, 2009). The existing weak health regulatory authorities with minimal monitoring of mining or occupational safety practices potentially expose miners to high levels of dust and particulate matter and increased risk of developing chronic respiratory diseases including COPD.

CONCLUSIONS

There is a substantial burden of COPD among young miners in Tanzania coupled with high rates of cigarette smoking and exceedingly high levels of occupational exposure to filterable particulate matter in the mining fields. These findings underscores the urgent need for a national social protection and legal framework for occupational health in Tanzania. This could be achieved through design and enforcement of vigilant approaches for safety regulations, promotion of workers' health and prevention of occupational diseases in Tanzania.

DECLARATIONS

Ethics approval and consent to participate

This study was approved by the National Institute for Medical Research (NIMR) Ethics Committee in Tanzania and conducted in accordance with Helsinki Declaration. All participants consented to participate in the study.

Consent to publish

All participants were requested for and consented for the permission to publish the study findings.

Availability of data and materials

All raw data pertaining to this study are stored at an institutional repository with secure back up. Both raw and processed data can be retrieved and made available to the third party upon reasonable request according to the institutional regulations.

Competing interests

The author declare no competing interests.

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Authors' contributions

NFM conceptualized, designed the study and obtained research grants. NFM developed training materials and offered training to the research assistants. He performed statistical analysis, wrote both the first and final version of the manuscript.

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