ORIGINAL RESEARCH

The prevalence of pulmonary tuberculosis among miners from the Karonga, Rumphi, Kasungu and Lilongwe Districts of Malawi in 2019

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Abstract

Introduction

Miners in sub-Saharan Africa have a greater risk of tuberculosis (TB) than any other working population in the world. In spite of the presence of large and vulnerable population of miners in Malawi, no previous study has aimed to assess the burden of TB among these miners. This study aimed to determine the prevalence of pulmonary tuberculosis (PTB) and health-seeking behaviour (HSB) in a population of miners in Malawi, and a range of associated factors. Our goal was to develop a method to identify missing cases of TB.

Methods

We conducted a cross-sectional study in the Karonga, Rumphi, Kasungu and Lilongwe districts of Malawi in 2019. We calculated frequencies, proportions, odds ratios (ORs) and their 95% confidence intervals (95% CIs), and used the chi-square test in STATA version15.1 to investigate the burden and magnitude of PTB in the mining sector. Bivariate and multivariate logistic regression models were also fitted for PTB and HSB.

Results

Of the 2400 miners approached, we were able to interview 2013 (84%). Of these, 1435 (71%) were males, 1438 (71%) had known HIV status and 272 (14%) had PTB. Multivariate analysis showed that the miners performing informal mining were 50% more likely to develop PTB compared with those in formal mining (adjusted odds ratio [AOR]=1.50, 95% CI: 1.10–2.05, *P*=0.01). A total of 459 (23% of 2013) miners had presumptive TB. Of these, 120 (26%) sought health care; 80% sought health care at health facilities. Multivariate analysis also showed that miners who experienced night sweats were less likely to seek health care compared with those without night sweats (AOR=0.52, 95% CI: 0.30–0.90, *P*=0.02).

Conclusion

The prevalence of PTB was higher among miners than in the general population. Consequently, targeted TB screening programmes for miners may represent a suitable strategy to adopt if we are to end TB by 2030. Poor health-seeking behaviours among miners is worrisome and further qualitative research is necessary to understand the barriers to accessing health care in these settings.

Key Words; Mines, pulmonary tuberculosis, PTB, Malawi, health-seeking behaviour, HSB

Introduction

In 2015, there were an estimated 10.4 million new cases of tuberculosis (TB)[1]. In the same year, Africa contributed 2,720,000 cases of TB and 743,000 deaths[2]. People living with HIV accounted for 1.2 million (11%) of all new TB cases in Africa. In 2015, there were an estimated 2.1 million new HIV infections worldwide, adding up to a total of 36.7 million people living with HIV[3]. TB has risen markedly in sub-Saharan African nations over the past two decades. Although the main explanation for rising TB rates has been the growth of HIV, mining is also considered to be a significant determinant of countrywide variation in TB among sub-Saharan African nations[4]. Miners are at an exceptionally high risk of TB[5]. Many mineworkers are migrants; this may expose them to multiple risk factors for TB, including HIV, health care disruptions and low socioeconomic status[6].

Miners in sub-Saharan Africa have a greater incidence of TB than any other working population in the world (reported to be 3000–7000 cases per 100,000 miners per year in some areas), and constitutes one of the largest pools of employed men in sub-Saharan Africa[7]. The incidence of TB among miners is estimated to be as much as ten times higher than in the populations from which they originate. The working conditions inside mines create a high-risk environment for TB transmission, resulting from silica dust exposure, as well as confined and poorly ventilated environments that are conducive to transmission[5]. Migration can also disrupt TB detection and care. Miners often have multiple treatment episodes with inappropriate therapy and high default rates; these cases can lead to drug-resistant TB[8].

Malawi, a southern African country, has a high TB burden with an estimated prevalence and incidence of 334 and 227

https://dx.doi.org/10.4314/mmj.v32i4.2

per 100,000 respectively[3]. As of 2015, there were 980,000 patients living with HIV/AIDS[9].The TB/HIV co-infection rate is estimated to be 53%[10]. Since mining is a significant risk factor for TB, the National Strategic Plan for TB 2015–2020 in Malawi focuses on a number of key interventions, including annual regular TB screening among miners and training health workers in mining companies so that they can take part in TB screening and management[11]. Although mining is still in its infancy in Malawi, the mining sector has been identified as one of the sectors that may lead to high levels of economic growth and development. The potential of mining as an industry was also confirmed by the World Bank's Mineral Sector Review in 2009 which projected that the value of mineral output would reach approximately US$250 million within 3 years of the report's publication. The legal and institutional frameworks governing the mining sector still remain weak and mining communities have limited access to basic health services. In some mining companies, the working conditions increase the exposure to factors that contribute to an increased risk of developing active TB. Improving the regulatory capacity of ministries or agencies which control these institutions will contribute significantly towards the reduction of TB burden in these settings[2]. There are 59 reported licensed mining companies which reported a total of 1979 workers within the formal sector in Malawi[12]. In 2002, there were nearly 45,000 individuals working in the mining sector, both in the formal and informal sector[13]. Members of the families of miners also share similar TB infection risk.

In spite of the presence of a large and vulnerable miner population in Malawi, no previous study has attempted to evaluate the burden of TB among this body of miners. As a result, information relating to TB in the mines is very limited. Therefore, we conducted this study to determine the prevalence of pulmonary tuberculosis (PTB) and TB/HIV co-infection among miners and assess their health seeking behaviour (HSB)in the event of chronic cough (≥1 weeks) in selected districts of Malawi in 2019. We specifically aimed to (a) determine the prevalence of PTB and HIV-TB co-infection among miners; (b) compare the prevalence of PTB by evaluating the characteristics of miners and (d) assess the HSB of miners in the event of chronic cough, night sweats, fever (≥1 weeks) and weight loss. The study was conducted under the Southern Africa Tuberculosis Project being implemented in Malawi and was funded by the World Bank.

Methods

Study design

This was a cross-sectional analytical study.

General setting

Malawi is a landlocked country in Southern Africa with a population exceeding 15 million as of 2014 (NSO 2015). Malawi is bordered by Tanzania in the northeast, Zambia in the northwest and Mozambique in the east, south and west. Malawi has 28 districts which are administratively divided into three regions; north, centre and south. Malawi is spread over 118,000 km^2 and is a highly mountainous country surrounded by rift valleys and plateaus. The majority of the population has a low socioeconomic status and low levels of literacy. Health coverage is provided to urban and rural areas, the latter taking place particularly through primary health care facilities. The Malawi National Tuberculosis Control Program (NTP) was established in 1964 to coordinate the national response to the fight against TB. In general, TB services are provided free of direct costs to clients at point of care and TB is among the priority Essential Health Package (EHP) conditions. Microscopy (both light and fluorescent) remains the mainstay for the diagnosis of TB in Malawi, with radiology as an adjunctive technology where available. Gene Xpert technology has been introduced in the past few years to increase the detection of TB, particularly for clients who are sputum smear negative and HIV positive. The National TB Reference Laboratory (NTRL) provides high level diagnostic services, including solid and liquid culture, to confirm the presence of TB in selected specimens from across the country. There are two NTRLs in the country.

Study setting

There are several mining activities across the country that include the exploration of minerals such as gemstones, copper, coal, nickel, niobium, tantalum, clinker and gypsum. In total, there are 10 mining districts in Malawi. This study focusses on four high impact districts: Rumphi, Kasungu, Lilongwe and Karonga. High impact districts in this study refer to districts with high TB notification rates and districts with greater levels of mining activities. There are two types of mining populations: those working in a formal mining sector and those working in the informal sector. Formal mining refers to companies that are licensed by the government of Malawi to operate whereas the informal sector refers to mining companies/individuals who operate without a government-issued license. The burden of TB is relatively high among miners and is 10–15 times higher than that of the general public. Furthermore, miners generally have poor access to health services[3].

Study population

This study included individuals working in mining industries and engaged in mining activities (hereafter referred to as active miners) in the four selected high impact districts of Malawi. The study was carried out in both formal and informal mining industries.

Sample size calculation and sampling procedure

We used a TB prevalence of 1000 per 100000 population among miners, an absolute precision of 0.4%, a confidence level of 95%, and a non-response rate of 10% to estimate a total sample of 2400. The sample size was distributed equally across the four districts for convenience. From each district, 600 active miners were expected to be recruited into the study consecutively from the mining industries. We further distributed the district sample equally into formal and informal mining sectors (300 in each sector).

Data collection

All of the active miners were screened for TB and tested for HIV until the desired sample size had been reached in each district. We assessed the HIV status of miners who were already receiving TB treatment. We also conducted TB screening and HIV testing among miners with an unknown HIV status. Active miners whose TB status was unknown were screened for TB and tested for their HIV status. There were four groups within the research team: one was involved in administering the questionnaire and identifying presumptive TB cases (this group featured a research assistant/data clerk), the second group consisted of laboratory technicians who collected sputum samples from presumptive TB cases. The third team were qualified radiographers who carried out digital X-ray screening. The digital X-ray system was mounted on a mobile van and the interpretation of X-ray results was performed by clinicians based on the results section of the client form. The fourth team member offered HIV counselling and testing to presumptive TB cases and featured HTC counsellors.

The study participants were recruited at the mining industry consecutively in a convenient manner. Employers were notified of the activity days before the screening process and asked to disseminate the purpose of our visit to the employees with the help of a research assistant to clarify any issues as they arose. Those present on the day of the interview were asked to participate one after another depending on the numbers that were released at a time by the employers to avoid disruption of services for those in the formal sector. In the informal sector, those available at a particular mining settlement were requested to take part in the study. A structured questionnaire was administered to all of the study participants in the order mentioned in the list. The first part of the questionnaire captured the demographic characteristics and exposure to mining activities. Details of the study were explained to the study participants and a consent form (written in the local language) was given to the participants for them to sign. Participation in the study was voluntary. After the subjects had provided consent, we recorded a range of information, including age, sex, marital status and education level. Each subject was then given a unique identification code; this was recorded on his/her form.

The miners were asked whether they were receiving TB treatment or not at the time of the interview. If they were receiving treatment, we ascertained the category of TB and HIV status. If the HIV status was not known, the subjects were referred to the HIV counselling and testing booth to receive an HIV test. If found not to be on treatment, the subjects were asked whether they have had cough, fever, night sweats for more than 1 week and weight loss. Those who admitted to all of these symptoms were treated as presumptive TB cases and proceeded with the questionnaire. Those who did not have the symptoms did not proceed with the diagnostic TB tests but were offered HIV testing services; their data were retained for analysis.

All presumptive cases were asked whether they sought any medical attention for their symptoms, where they went and what treatment they received. Patients at this stage were directed to the X-ray station where their chest radiographs would be acquired.

The study followed the national diagnosis algorithm for the diagnosis of TB and national policy when dealing with at-risk groups; X-rays were carried out in parallel with symptomatic screening for all presumptive cases[14]. The National TB diagnosis algorithm involves the symptomatic screening of patients and those found to be presumptive cases undergo further radiographical screening for specific target groups, including health workers, prisoners, those in mines and those in high burden sites. Sputum submission for microscopy is universal for all patients and where available, the Gene Xpert system is used (as is the case with mobile TB diagnostic vans). Those found to be MTB detected Rif Negative are placed on standard TB treatments while those that are Rif Positive are either placed on a short-term regimen or individualised treatment plans. Those found to be negative on the Gene Xpert system are placed on trial antibiotics (see Figure 1).

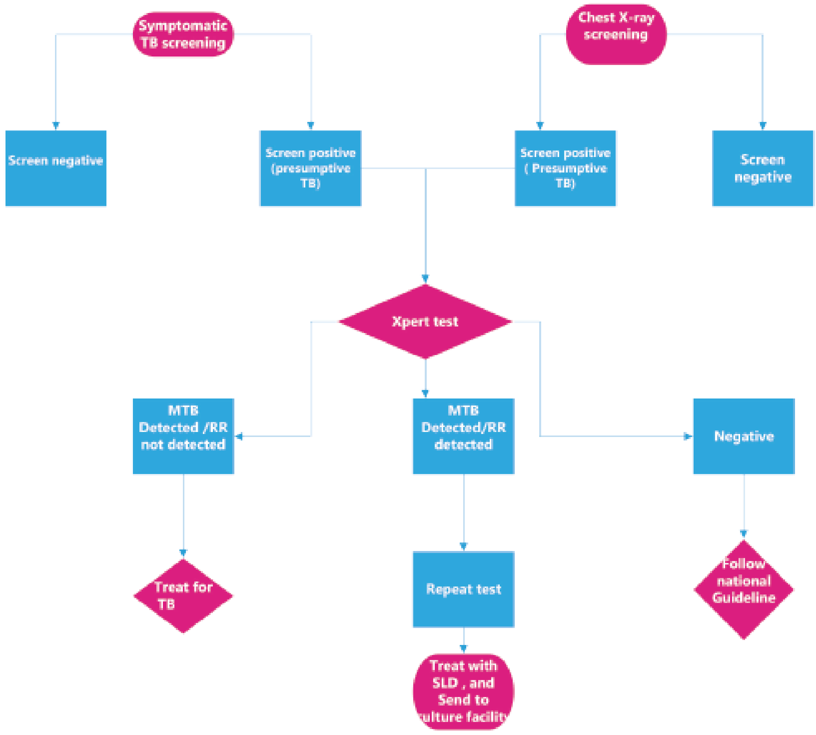

Figure 1. Schematic showing the national diagnostic algorithm

All presumptive cases received a chest X-ray performed by qualified radiographers from a mobile van with a mounted X-ray machine. X-ray films were interpreted by a clinician stationed at this section. All of the miners also underwent sputum examination by submitting two samples: one at the time of examination and another on the morning of the following day for bacteriological confirmation. The samples and laboratory forms were labelled using the identification code given at registration. All samples were kept in cold transportation boxes and sent to the national reference laboratories within 4 days of collection. At the National Reference Laboratory, the samples were examined using microscopy and those that were smear negative were further examined using the Gene Xpert system. All clients with confirmed PTB were informed immediately and given access to treatment with anti-tuberculosis drugs at their nearest TB registration site.

Finally, the miners underwent HIV testing and counselling in order to ascertain their HIV status. The first HIV test was conducted using 'Determine' while confirmatory HIV tests were conducted by 'Uni-Gold' whenever the first HIV test was positive. Determine is a rapid test manufactured by Abbott solutions whose headquarters is in Illinois, USA. SIMILARLY unigold is also a rapid test made by Trinity Biotech whose headquarters is in Ireland , Bray-co.wicklow). HIV test results were confidential and made known only to the owner. All clients with HIV positive results were informed immediately and given access to HIV care clinics.

Data variables

We collated a wide range of data variables for analysis: screened for TB (yes/no), presumptive TB (yes/no), currently on TB treatment (yes/no), smear result, Gene Xpert result, X-ray findings, newly diagnosed TB (yes/no), type of TB (Sm+/Sm-), category of TB (new/retreatment), HIV test result (yes/no/indeterminate/not done), type of mining population (formal/informal), type of mining industry, duration of exposure to mining activities), type of mining population (formal/informal), sex (male/female), age, marital status, level of education, religion, duration of exposure to mining activity, type of mining activity, body weight loss, fever, HSB of the miners in the event of chronic cough ≥1 week): cough for more than 2 weeks, (yes/no), sought health service (yes/no), if yes, after how many days, type of facility from where health care sought (MoH/Private/CHAM/Industrial/traditional/Other), and type of treatment received (allopathic/traditional/others).

Data management and data analysis

All data were entered into Epi-Info version 3.5.3. This is a public domain software package developed by the US centre for disease control and prevention headquarters of which is in Atlanta, Georgia. The system included: (1) a data entry module with built-in check codes; (2) a data monitoring and analysis module with built-in monitoring programs to check for duplicates, missing values and inconsistencies; and (3) a reporting module to automatically generate summary reports at the cluster and central level. We exported the data to STATA version 15.1 (Stata Corp., College Station, TX) for further data management and analysis.

We analysed data using proportions, frequencies, odds ratios (ORs), medians and interquartile ranges (IQRs). Measures of association were assessed using odd ratios and their associated 95% confidence intervals (95% CIs) and chi-square tests. We conducted both bivariate and multivariate analyses to investigate the effect of various demographic and clinical factors on the prevalence of PTB and HSB.

Age and sex were entered as a priori variables in multivariate analysis when investigating the effect of sociodemographic and clinical characteristics on the prevalence of PTB. However, age, sex, coughing, fever, night sweats and body weight loss were entered as a priori variables when multivariate modelling the effect of the sociodemographic factors on HSB. For a variable to be considered for inclusion in the multivariate model, we tested for statistical significance at P=0.2. We built the statistical model using a forward selection method and only variables that were statistically significant (P=0.05) were maintained in the model. We assessed the statistical models for sensitivity and specificity using the *estat classification* command. We presented the data using tables and figures as appropriate.

Ethics approval

The study was approved by the Malawi National Health Science Research Committee in Lilongwe, Malawi (protocol #: 18/01/1954). The study was also approved by The Union Ethics Advisory Board, Paris, France. We obtained individual consent from all the study participants.

Results

Characteristics of the interviewed miners

Of the 2400 miners expected to be interviewed, a total of 2013 (84%) miners took part in this study. Of these, 1426 (71%) were males; 557 (27%) were from Kasungu district while 463 (23%) were from the Rumphi district; 1079 (56%) were involved in formal mining; 570 (28%) were aged 25–34

Table 1: Characteristics of miners that were interviewed in Malawi in 2019

Characteristics (n= 2013)	n (%)
Total	2013 (100)
District	
Karonga	508 (25)
Kasungu	557 (27)
Lilongwe	487 (24)
Rumphi	463 (23)
Sex	
Female	587 (29)
Male	1426 (71)
Age group (years)	
15-24	444 (22)
25-34	570 (28)
35-44	495 (25)
45-54	280 (14)
55-64	136 (7)
65+	88 (4)
Education level	
None	143 (7)
Primary	1063 (52)
Secondary	676 (33)
Tertiary	70 (4)
Missing	72 (4)
Marital status	
Married	1477 (73)
Separated	163 (8)
Never Married	338 (17)
Missing	36 (2)
Religion	
Christian	1870 (93)
Islam	74 (4)
Other	69 (4)
Type of mining population	
Formal	1079 (54)
Informal	934 (46)
Mining activities	
Cement	301 (15)
Coal	579 (29)
Quarry	1100 (55)
Other	33 (2)
Years involved in mining	
0-3.5	1125 (56)
3.6+	888 (44)
HIV status	
Negative	1409 (70)
Positive	29 (1)
Not tested	574 (29)
Indeterminate	1 (<1)

The prevalence of PTB and HIV/TB co-infection among miners

A total of 272 (14%) of the 2013 miners had PTB. Out of the 272 miners, 25% were bacteriologically confirmed. HIV was ascertained in 1438 (71%) of the 2013 miners. Amongst the 1438 miners with a known HIV status, 29 (2%) were HIV positive. Of the 29 miners diagnosed to be HIV positive, 8 (28%) were also diagnosed with PTB. The likelihood of PTB amongst the miners diagnosed with HIV was similar when compared between those with and without HIV (OR: 2.00, 95% CI: 0.80–5.03, P=0.14).

Factors associated with the prevalence of PTB among the miners

We used a total of 1924 (96% of 2013) records for our analyses that had a complete dataset. The factors associated with the prevalence of PTB are shown in Table 2. Under bivariate analysis of the factors associated with prevalence of PTB, the following factors showed strong evidence for an association with the prevalence of PTB: district, age, education level, mining activities, years of mining and marital status (see Table 2). The highest prevalence of PTB was observed in Lilongwe district (20% of 467 miners) while the lowest prevalence of PTB was observed in Karonga district (7% of 495 miners). The prevalence of PTB was the highest amongst those who were married compared with those who were not married (see Table 2). The likelihood of PTB increased with increasing age. The miners involved in informal mining had a significantly higher likelihood of PTB

https://dx.doi.org/10.4314/mmj.v32i4.2

compared with those involved in formal mining (OR=1.81, 95% CI: 1.39–2.37, *P*<0.001). The miners that had been performing mining activities for more than 3.5 years had a significantly higher risk of PTB (OR=1.88, 95% CI: 1.44–2.46, *P*<0.001). Miners involved with the coal industry had a significantly lower likelihood of PTB (OR=0.30, 95% CI: 0.19–0.49, *P*<0.001). Multivariate analysis showed that the following factors were associated with the prevalence of PTB: district, sex, and whether the miner was involved in formal or informal mining (see Table 2). After adjusting for sex, age and type of mining population, we found that PTB was higher in all other districts when compared with the Karonga district (see Table 2).

Table 2: Prevalence of pulmonary tuberculosis (PTB) and factors associated with PTB amongst the miners in Malawi in 2019

Characteristics (n=1924)	Total number of miners n (%)	Prevalence of PTB n (%)	Unadjusted estimates		Adjusted estimates	
			OR (95%CI)	P-value	OR (95%CI)	P-value
District						
Karonga	495 (100)	37 (7)	1.00		1.00	
Kasungu	518 (100)	93 (18)	2.71 (1.81-4.05)	<0.001	2.38 (1.57-3.62)	<0.001
Lilongwe	457 (100)	92 (20)	3.12 (2.08-4.68)	<0.001	2.69 (1.77-4.10)	<0.001
Rumphi	454 (100)	35 (8)	1.03 (0.64-1.67)	0.89	1.14 (0.70-1.87)	0.60
Sex						
Female	558 (100)	63 (11)	1.00		1.00	
Male	1366 (100)	194 (14)	1.30 (0.96-1.76)	0.09	1.85 (1.30-2.62)	0.001
Age group (years)						
15-24	422 (100)	17 (4)	1.00		1.00	
25-34	547 (100)	47 (9)	2.24 (1.27-3.96)	0.01	2.35 (1.32-4.18)	0.04
35-44	475 (100)	67 (14)	3.91 (2.26-6.78)	<0.001	4.16 (2.38-7.25)	<0.001
45-54	268 (100)	55 (21)	6.15 (3.48-10.86)	<0.001	5.68 (3.19-10.11)	<0.001
55-64	126 (100)	38 (30)	10.29 (5.55-19.06)	<0.001	9.40 (5.01-17.63)	<0.001
65+	86 (100)	33 (38)	14.83 (7.73-28.45)	<0.001	13.94 (7.11-27.34)	<0.001
Education level						
None	141 (100)	32 (23)	1.00			
Primary	1044 (100)	159 (15)	0.61 (0.40-0.94)	0.03		
Secondary	669 (100)	65 (10)	0.37 (0.23-0.59)	<0.001		
Tertiary	70 (100)	1 (1)	0.05 (0.01-0.37)	0.003		
Marital status						
Married	1436 (100)	217 (15)	1.00			
Separated	161 (100)	21 (13)	0.84 (0.52-1.36)	0.49		
Never Married	327 (100)	19 (6)	0.35 (0.21-0.56)	<0.001		

table 2 cont...

Characteristics (n=1924)	Total number of miners n (%)	Prevalence of PTB n (%)	OR (95%CI)	P-value	OR (95%CI)	P-value
Religion						
Christian	1820 (100)	240 (13)	1.00			
Islam	74 (100)	10 (14)	1.07 (0.54-2.11)	0.86		
Other	42 (100)	9 (21)	1.80 (0.85-3.81)	0.12		
Type of mining population						
Formal	1032 (100)	105 (10)	1.00		1.00	
Informal	892 (100)	152 (17)	1.81 (1.39-2.37)	<0.001	1.50 (1.10-2.05)	0.01
Mining activities						
Cement	279 (100)	45 (16)	1.00			
Coal	563 (100)	31 (6)	0.30 (0.19-0.49)	<0.001		
Quarry	1050 (100)	177 (17)	1.05 (0.74-1.51)	0.77		
Other	32 (100)	4 (13)	0.74 (0.25-2.22)	0.60		
Years involved in mining						
0-3.5	1078 (100)	109 (10)	1.00			
3.6+	846 (100)	148 (17)	1.88 (1.44-2.46)	<0.001		

Sensitivity= 3.9%

Specificity=99.1%

Positive predictive value=40.0%

Negative predictive value=87.0%

Correctly classified=86.4%

*P-values from logistic regression

After adjusting for age, district and type of mining population, the male miners were 85% more likely to have PTB compared with female miners (adjusted odds ratio [AOR]=1.85, 95% CI: 1.30–2.62, *P*=0.001). After adjusting for age, sex and district, the miners involved in informal mining were 50% more likely to develop PTB compared with those involved in formal mining (AOR=1.50, 95% CI: 1.10–2.05, *P*=0.01). There was an increasing trend in the adjusted OR for PTB by age (see Table 2). The AOR of PTB had either increased or decreased by an average of 14% compared with the crude OR indicating that there was a confounding effect, as shown in Table 2.

Factors associated with health-seeking behaviour among miners

A total of 459 (23% of 2013) miners had one of the following symptoms: coughing, body weight loss, night sweats and fever. The median duration of cough was 7 days (IQR: 3–21). The median duration of body weight loss was 7 days (IQR: 7). The median duration of night sweats was 7 days (IQR: 4–7). The median duration of fever was 7 days (IQR: 3–7). Of the 459 subjects, 120 (23%) sought health care. Of these, 80 (67%) sought care at a facility owned by the Ministry of Health, 13 (11%) sought care at faith-based facilities, 15 (13%) sought care at private clinics, 9 (8%) sought care at other clinics and 3 (3%) sought care at clinics based within their own companies. The prevalence of HSB and its associated factors are shown in Table 3. Bivariate analysis showed that district, age, marital status and mining activities were the key factors associated with HSB. The miners from Kasungu were three times more likely to seek health care than those from Karonga (OR=3.03, 95%

CI: 1.59–5.76, *P*=0.001). Male miners were less likely to seek health care than their female counterparts (OR=0.62, 95% CI: 0.39–0.99, *P*=0.045). Being aged either 45–54 years or 65+ years was associated with a higher likelihood of HSB compared with those aged 15–24 years (see Table 3). The

Table 3: Factors associated with health seeking behaviour (HSB) amongst the miners with pulmonary tuberculosis in Malawi in

Characteristics (n=459)	Total number of miners n (%)	Prevalence of HSB n (%)	Unadjusted estimates		Adjusted estimates	
			OR (95%CI)	P-value*	OR (95%CI)	P-value*
District						
Karonga	96 (100)	15 (16)	1.00		1.00	
Kasungu	153 (100)	55 (36)	3.03 (1.59-5.76)	0.001	2.65 (1.33-5.26)	0.01
Lilongwe	110 (100)	26 (24)	1.67 (0.83-3.38)	0.16	1.60 (0.77-3.34)	0.21
Rumphi	100 (100)	24 (24)	1.71 (0.83-3.49)	0.15	1.71 (0.82-3.59)	0.16
Sex						
Female	111 (100)	37 (33)	1.00		1.00	
Male	348 (100)	83 (24)	0.62 (0.39-1.00)	0.045	0.62 (0.37-1.02)	0.06
Age group (years)						
15-24	88 (100)	14 (16)	1.00		1.00	
25-34	131 (100)	35 (27)	1.93 (0.97-3.84)	0.062	1.98 (0.98-4.03)	0.06
35-44	115 (100)	25 (22)	1.47 (0.71-3.03)	0.30	1.61 (0.76-3.39)	0.21
45-54	61 (100)	24 (39)	3.43 (1.59-7.39)	0.002	3.18 (1.43-7.05)	0.004
55-64	37 (100)	10 (27)	1.96 (0.78-4.93)	0.15	1.67 (0.64-4.34)	0.30
65+	27 (100)	12 (44)	4.23 (1.64-10.93)	0.003	3.69 (1.35-10.04)	0.01
Education level						
None	41 (100)	9 (22)	1.00			
Primary	250 (100)	66 (26)	1.28 (0.58-2.81)	0.55		
Secondary	158 (100)	43 (27)	1.33 (0.59-3.01)	0.50		
Tertiary	10 (100)	2 (10)	0.89 (0.16-4.95)	0.89		
Marital status						
Married	368 (100)	100 (27)	1.00			
Separated	34 (100)	12 (35)	1.46 (0.70-3.06)	0.32		
Never Married	57 (100)	8 (14)	0.44 (0.20-0.96)	0.04		
table 3 cont...						
Religion						
Christian	433 (100)	113 (26)	1.00			
Islam	13 (100)	4 (29)	1.26 (0.38-4.17)	0.83		
Other	13 (100)	3 (23)	0.85 (0.23-3.14)	0.81		
Type of mining population						
Formal	244 (100)	56 (23)	1.00			
Informal	215 (100)	64 (30)	1.42 (0.94-2.16)	0.10		
Mining activities						
Cement	82 (100)	28 (34)	1.00			
Coal	116 (100)	20 (17)	0.40 (0.21-0.78)	0.007		
Quarry	261 (100)	72 (28)	0.73 (0.43-1.25)	0.26		
Years involved in mining						
0-3.5	248 (100)	63 (25)	1.00			
3.6+	211 (100)	57 (27)	1.09 (0.72-1.65)	0.70		
Coughing						
No	112 (100)	30 (27)	1.00		1.00	
Yes	347 (100)	90 (26)	0.96 (0.59-1.55)	0.86	1.06 (0.60-1.88)	0.83
Body weight loss						
No	373 (100)	91 (24)	1.00		1.00	
Yes	86 (100)	29 (34)	1.57 (0.95-2.61)	0.08	1.42 (0.80-2.53)	0.24
Night sweats						
No	333 (100)	99 (28)	1.00		1.00	
Yes	126 (100)	27 (21)	0.70 (0.43-1.15)	0.16	0.52 (0.30-0.90)	0.02
Fever						
No	304 (100)	74 (24)	1.00		1.00	
Yes	155 (100)	46 (30)	1.31 (0.85-2.02)	0.22	1.41 (0.83-2.38)	0.20

miners that had never been married had a lower likelihood of HSB compared with those who were married (OR=0.44, 95% CI: 0.20–0.96, *P*=0.04). Similarly, those mining coal had a lower likelihood for HSB compared with those working in cement mining (OR=0.40, 95% CI: 0.21–0.78, *P*=0.01). Multivariate analysis showed that district, age and having night sweats were the most significant factors associated with HSB (see Table 3). After adjusting for age, sex, coughing, night sweats, body weight loss and fever, the miners from Kasungu district were almost three times more likely to seek health care than those from Karonga district (AOR=2.64, 95% CI: 1.33–5.26, *P*=0.01). Furthermore, after adjusting for district, sex, coughing, night sweats, body weight loss and fever; those aged either 45–54 years or 65+ years were associated with a higher likelihood of HSB compared with those aged 5–24 years (see Table 3).

After adjusting for age, sex, district, coughing, body weight loss and fever, the miners with night sweats were less likely to seek health care compared with those without night sweats (AOR=0.52, 95% CI: 0.30–0.90, *P*=0.02). The AOR for HSB had either increased or decreased by an average of 11% compared with the crude OR indicating that there was a confounding effect, as shown in Table 3.

Discussion

The PTB prevalence of 14% amongst miners is quite worrying. The prevalence of PTB was 80% higher in males and increased with increasing age. Moreover, the prevalence of PTB was 46% higher in the informal mining population. The HIV ascertainment of 71% amongst the miners was sub-optimal while the prevalence of HIV was 2% among the miners. The fact that only 26% of the miners with cough or night sweats, or body weight loss, or fever, reported having sought care is also of great concern for TB prevention efforts amongst the miners. The HSB was lower amongst males and miners with night sweats but significantly higher amongst those aged 45–54 years and 65+ years compared with those aged 15–24 years.

The prevalence of PTB amongst the miners was 14% (272/2013) and was therefore amongst the highest in Malawi and other similar settings. The observed prevalence of TB was much higher than the 1014 per 100,000 reported in the 2013/2014 survey[15]. In other similar settings, a high prevalence of PTB has been reported in sub-Saharan African

https://dx.doi.org/10.4314/mmj.v32i4.2

countries[16,17]. There is variation in the risk factors for PTB identified in different countries. One of the factors associated with PTB was the number of years of mining activity and was therefore similar to that reported previously for Zambia, South Africa and other sub-Saharan Africa Countries, or other similar settings[16-18]. We found an increasing prevalence of PTB with an increasing duration of mining; this may have implications to exposure to silica. Consistent with other studies that have studied the effect of HIV on TB[19,20], we also found that miners with HIV were three times more likely to have PTB. We also identified sex differences in the prevalence of PTB amongst the miners. This concurs with other studies that have investigated age and sex differences associated with PTB in different populations[21]. To our knowledge this is the first study to investigate the factors associated with PTB in miners in Malawi. Other countries have also stated that TB is a significant health problem among miners, although only a small amount of new data has arisen since the 2015 TB strategy[22].

Furthermore, we also found that miners involved in informal mining were almost 50% more likely to develop PTB. This could be attributed to the fact that most of these miners often operate without the use of wet methods to reduce silica exposures or operate without protective wear. In some studies in similar settings, airborne crystalline silica exposure exceeded the recommended limits for all tasks monitored with an average exposure of 16.85 mg/m^3 for underground drilling by the U.S. National Institute for Occupational Safety and Health (NIOSH) and 0.19 mg/m^3 for aboveground operations[23]. The use of wet methods have been proposed to reduce exposures and the risk of TB and silicosis in miners involved in informal mining[23]. Knowledge of HIV status among persons at risk of developing TB is a prerequisite for subsequent HIV care and management. Our study reported that 71% (1438/2013) of the miners had a known HIV status. The reported HIV ascertainment in our study is lower than the targets set by the UNAIDS 90-90-90 programme[24]. Another study, conducted in Mali, also observed sub-optimal HIV ascertainment amongst miners[25]. Further research would be important to understand the low HIV ascertainment surrounding these mines although most of the miners were males, often with poorer levels of HSB; these could be key factors contributing to these findings. Our findings suggest that the targeted HIV testing of miners would help to ensure that all the miners are offered the test and have a known HIV status.

The prevalence of HIV in the miners included in our study was 29/1438 (2%). The observed HIV prevalence was, therefore, lower than in most populations of Malawi and other similar settings[25-27]. The low HIV prevalence may be because most of the miners do not move around extensively as they have a static site of operation. As mining is predominantly carried out by men, the static sites of operation may have resulted in low rates of casual unprotected sexual encounters, thereby reducing the risk of HIV acquisition. Of the 459 miners experiencing coughing, body weight loss, night sweats and fever, 120 (26%) sought health care. This low level of HSB may have arisen because most of the mines are located at sites that are distanced from health facilities. There were key differences in HSB according to age, district, marital status and type of mining activities. Similar to other studies conducted in sub-Saharan Africa, our study found that those who were never married had a higher likelihood of HSB[28,29]. Furthermore, some other studies have also found that older persons had an increased likelihood for HSB than younger persons[28,29]. The Malawi National Tuberculosis Control Programme should consider conducting an in-depth analysis to further understand how client-based factors, provider-based factors, perceptions, social and demographic factors, cost, social networks, biological signs and symptoms work synergistically to produce a pattern of HSB amongst the miners[30]. The major strength of this study is its large sample size. To our knowledge, this is the first large study that has been conducted on miners in Malawi. However, there are some limitations that need to be considered. For example, this study only focused on four districts; thus, our results may not be generalisable to all 28 districts of Malawi. Furthermore, some other studies included other factors in their analyses, including the intensity of exposure to silica, smoking and alcohol intake; these factors are strongly associated with PTB[22,23]. In our study, we did not consider these factors. Furthermore, this study assessed only quantitative aspects of HSB among miners. Future studies should consider conducting both qualitative and quantitative aspects of HSB among miners. We also acknowledge that our response rate at 84% was low; the WHO recommendation for response rate in TB studies is 85%.

In conclusion, this is the first study to investigate factors associated with PTB and HSB among miners in Malawi. The prevalence of PTB amongst the miners was high while the prevalence of HSB was low. The observed prevalence of PTB among the miners was higher than in the general population. Therefore, the targeted TB screening of artisanal miners may represent a key strategy to adopt if we are to end TB by 2030. Artisanal miners are those small scale miners not affiliated with any formal mining company. There is also a need for the Malawi National TB Control Programme to understand the drivers and facilitators of HSB among miners with presumptive TB. This could be achieved by conducting a qualitative study on HSB. Furthermore, the Malawi National TB Control Programme may consider performing a nationwide study so that we can obtain a nationwide understanding of the prevalence of PTB and HSB among the wider body of miners.

Acknowledgements

The authors wish to acknowledge the miners that took part in this study.

Funding

Funding for this project was provided by the Ministry of Health, Government of Malawi/World Bank TB in the Mines Project, Malawi. The funders had no role in the study design, data collection and analysis, decision to publish, or the presentation of the manuscript.

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