Occupational lung disease among Basotho ex-miners in a large outreach medical assessment programme

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Keywords: Lesotho, gold miners, silicosis, tuberculosis, burden of disease

How to cite this paper: Maboso BM, Moyo DM, Muteba KM, Govender VG, Barnes DF, Maama-Maime LBM, Makiti SJ, Lerotholi M, Ehrlich R. Occupational lung disease among Basotho ex-miners in a large outreach medical assessment programme. Occup Health Southern Afr. 2020; 26(4):145-152.

ABSTRACT

Background: Current initiatives in southern Africa to medically assess former migrant miners for silicosis and tuberculosis, including statutory and lawsuit-derived compensation programmes, require burden of disease information.

Objective: To use clinical information collected on ex-miners examined at the Occupational Health Service Centre (OHSC) in Lesotho, operated under the Tuberculosis in Mining Sector in Southern Africa (TIMS) project, to measure the burden of lung disease and respiratory impairment.

Methods: Demographic, occupational and medical history information, chest radiology, spirometry, GeneXpert testing for tuberculosis, and pulse oximetry outcomes were analysed, and descriptive summary measures calculated, in a group of ex-miners examined in 2017 and 2018.

Results: The study sample comprised 2 758 Basotho former underground miners, with median age of 62 years and median length of service of 28 years. Among ex-gold miners (n = 2 678), disease prevalence was high: radiological tuberculosis (consistent with previous or current disease) 60.9%, silicosis 42.5%, HIV 30.7%, silicotuberculosis 25.7%, and current active tuberculosis 6.8%. Of those with tuberculosis diagnosed microbiologically, 6.7% had no radiological evidence of tuberculosis and 54.1% did not report cough.

Conclusion: The findings have public health and compensation implications. There are large numbers of ex-miners with potentially compensable disease under both the statutory system and a settlement trust set up following litigation. This overlaps with a tuberculosis-HIV co-epidemic which requires screening and treatment for tuberculosis and HIV, and managing a considerable disability and care burden on families and the Lesotho health system. Coordinated planning and substantial resources are needed for these programmes to do justice to their mandates.

INTRODUCTION

As a result of the late 20th century epidemic of silicosis, tuberculosis and HIV in the South African mining industry, the burden of lung disease in ex-miners, particularly gold miners, distributed across rural areas of South Africa and neighbouring countries, has become a subject of intense interest and the target of three major initiatives.

In 2016, the Tuberculosis in the Mining Sector (TIMS) programme, funded by the Global Fund for AIDS, Tuberculosis and Malaria, commenced.[1] This effort followed recognition by the Southern African Development Community (SADC) of the role of mining, and particularly that of the South African gold mining industry, as the dominant industry in the region contributing to the regional tuberculosis epidemic, and of the desire by the SADC to harmonise tuberculosis management across the region.[2-4] The settlement of a class action suit for both silicosis and tuberculosis in 2019 created the Tshiamiso Trust, which is responsible for the identification, contact and medical assessment, where possible, of all former dust-exposed employees of the six major mining companies that were sued.[5] The Trust covers about 70% of all mineworkers recruited into the South African gold mining industry. In parallel with the class action suit and some earlier lawsuits, political pressure built up to reform the ailing state miners' compensation system.[6-8] This has resulted in the office of the Compensation Commissioner for Occupational Diseases, in cooperation with the large mining companies and some international agencies, setting up or expanding examination centres for ex-miners to facilitate access to benefit medical examinations (BMEs).[9]

For the past century, the Crown Colony of Basutoland, which became the Kingdom of Lesotho in 1966, has been a major source of miners for the South African gold mines. Lesotho is a landlocked country within the borders of South Africa, with a population of 2 255 370 in 2020.[10] It is therefore home to a large number of ex-miners who were employed in the South African gold, platinum and coal mines. Large-scale recruitment of black migrant workers occurred from the 1970s to the 1990s, particularly in the gold mining sector. During the peak employment period of 1988 to 1992, based on data supplied by TEBA Ltd., the major South African mining recruiting organisation, approximately 870 000 miners passed through the South African mining industry, of whom approximately 15% (132 500) were from Lesotho.[11]

There are few sources of information on occupational lung diseases among Basotho mine workers. A 2004 hospital survey of tuberculosis

Table 1. Variable definitions, measurement techniques, and data quality

Variable	Means of measurement/collection	Quality control/comment
Age (years)	Calculated from birth date on ID document and date of visit to OHSC	
Length of mine service (years)	Estimated from first and last year of service	A one-week validation check of clinical files found 83% with a confirmatory record of service
Occupation (high dust, low dust)	Longest job occupied. High dust: rock drill operator, winch operator, stope team member, loader operator, construction worker, blasting assistant, etc. Low dust: belt attendant, chair lift attendant, loco operator, general worker, etc.	0.2% missing
Commodity: (gold, platinum, coal)	Commodity sector of longest service	
Smoking history (ever, never)	Recorded by medical practitioner. Ever: ever smoked for ≥ 6 months. Never: never smoked or smoked for < 6 months	1.1% missing
Silicosis (ILO > 1/0, with or without tuberculosis)	Chest X-ray classified by medical practitioner with ILO classification training, after treatment of attendee for any active tuberculosis	Random sample of 300 chest X-rays read independently by two specialist occupational physicians familiar with ILO classification. Reported 80-90% and 90% agreement, respectively, with clinic reading
Silicotuberculosis	Silicosis plus tuberculosis, active and/or radiological, including parenchymal, pleural or mediastinal abnormality suggestive of inactive or active tuberculosis	As for silicosis
HIV status	HIV test offered to all not on ART. HIV-positive: status known (shown in participant's medical booklet), or diagnosed at the OHSC (Uni-Gold™ rapid test, Trinity Biotech). HIV-negative: tested negative at OHSC or elsewhere within previous 12 months (shown in medical booklet)	0.6% missing
History of past tuberculosis treatment	Self-reported	Where possible, verified on Lesotho medical booklet, mine exit medical certificate, MBOD certificate or tuberculosis DOT card
Radiological changes suggestive of tuberculosis	Read by medical practitioner. Parenchymal, pleural or mediastinal abnormality suggestive of inactive or active tuberculosis	As for silicosis
Current active tuberculosis	Tuberculosis diagnosed at OHSC on positive GeneXpert with or without clinical and/or radiological features of tuberculosis, or tuberculosis diagnosed elsewhere and on tuberculosis treatment at time of attendance	GeneXpert testing of sputum sought on all attendees, regardless of presumptive tuberculosis status, but excluding those already on tuberculosis treatment or within 12 months of treatment completion. Sputum obtained from 96% of attendees
Cough (> 2 weeks)	Recorded by medical practitioner	0.4% missing
Shortness of breath (any)	Self-reported	0.6% missing
Shortness of breath at rest	Assessed clinically by medical practitioner	
Peripheral capillary oxygen saturation (SpO_2) (%)	Measured on multi-parameter patient monitor (Aquarius G91025, Aquarius Electronics, London, UK)	11.9% missing
BMI (kg/m^2)	Height and weight measured on a Charder scale (HM 20IM)	
FEV_1, FVC, FEV_1/FVC as % of predicted	Measured on Easy on-PC spirometer (ndd Medizintechnik AG, Zurich, Switzerland). Predicted value 0.9 x ECCS (European Community of Coal and Steel) reference value	ATS criteria applied. Spirometer calibrated regularly during testing and annually by supplier. Only results that met validity criteria included in the analysis

ART: antiretroviral therapy; OHSC: Occupational Health Service Centre; DOT: directly observed treatment. BMI: body mass index; FEV_1: forced expiratory volume in one second; FVC: forced vital capacity; ATS: American Thoracic Society

cases in Maseru reported that 38.4% had worked in the South African (mainly gold) mines.[12] A prevalence survey, conducted in 2001, of Basotho gold miners one year after retrenchment, revealed a profound burden of disease: past tuberculosis 26%, HIV 22.3%, silicosis 24.6%, and active tuberculosis 6.2%.[13] A one-year follow up of this cohort estimated a minimum annual tuberculosis incidence of 3 085 per 100 000, and an annual HIV incidence of 5.2%.[14] The ex-miner experience occurs against the background of a continuing co-epidemic of tuberculosis and HIV in Lesotho. In 2018, Lesotho recorded an HIV prevalence of 23.6%[15] and the world's highest tuberculosis annual incidence of 611 per 100 000. The tuberculosis incidence rate was three and five times that of the World Health Organization (WHO) Africa region and global rates, respectively.[16] Tuberculosis-related mortality rates were equivalently high.[16]

An opportunity to update our knowledge of the burden of disease in this neglected population arose from the TIMS programme. The main purpose of the programme was to screen miners (currently or previously employed), their families, and other residents of mine-sending communities for tuberculosis, and to link them to treatment as needed. Another purpose was to screen miners for lung disease that qualifies as occupational disease under the Occupational Diseases in Mines and Works Act (ODMWA), viz. pneumoconiosis, permanent obstruction of the airways, and tuberculosis (meeting eligibility criteria), and to assist miners with these conditions to apply for compensation in South Africa.

Mafeteng is one of the 10 politico-administrative districts in Lesotho. The Mafeteng Occupational Health Service Centre (OHSC) is one of 11 TIMS centres set up in southern Africa to offer screening services. From January to September 2017, Mafeteng OHSC was the only centre offering such services in Lesotho. In October 2017, an OHSC was opened in the capital city of Maseru. Thereafter, the Mafeteng OHSC serviced miners from about half the country, including Mafeteng, Qacha's Nek, Quthing, Mohale's Hoek and part of Maseru.

The objective of our study was to estimate the burden of disease in a sample of ex-miners examined under the TIMS programme in Lesotho, using data collected at the Mafeteng OHSC. Of interest were the diseases silicosis, pulmonary tuberculosis and HIV, and related indicators of respiratory impairment, namely, lung function and arterial oxygen saturation. The focus was on miners who had worked underground in the gold mining sector at some stage of their mining careers.

METHODS

A cross-sectional retrospective record review was undertaken on ex-miners who attended the Mafeteng OHSC from January 2017 to November 2018. Invitations to miners (active and former) to have screening examinations were extended throughout Lesotho by means of public gatherings, media (radio stations), word of mouth, outreach campaigns, and civil society organisations. Participants were thus self-selected rather than randomly selected from a sampling frame.

Included in the study were ex-miners who had worked underground in South African gold, coal, and/or platinum mines for a minimum period of 12 months. During the study period, Mafeteng OHSC serviced 3 166 individuals, including active and ex-miners, their families and members of their communities. Of these, 2 758 (87.1%) met the inclusion criteria.

MEASUREMENT

The Mafeteng OHSC was equipped to undertake digital radiography, GeneXpert (Cepheid, USA) tuberculosis testing (an automated diagnostic test, endorsed by the WHO, identifies *Mycobacterium tuberculosis* DNA and resistance to rifampicin), spirometry and peripheral capillary oxygen saturation (SpO_2) measurements. Participants' histories (personal, medical and occupational) were recorded by the OHSC medical practitioner.

This analysis was conducted using data collected as part of routine clinical operations. A data extraction tool was developed,

Table 2. Demographic and exposure characteristics of ex-miners examined at Mafeteng OHSC, 2017–2018 (N = 2 758)

Characteristic	n	Median	IQR	Range
Age (years)	2 692	62	57–68	28–98
Mine exposure (years)	2 758	28	20–34	1–52
Characteristic	**n**	**%**	**95% CI**	
Age group (years)				
< 39	23	0.8	0.4–1.2	
40–59	958	34.7	32.9–36.5	
≥ 60	1 711	62.1	60.3–63.9	
Occupation				
High dust	2 005	72.7	71.0–74.4	
Low dust	748	27.1	25.4–28.8	
Commodity				
Any gold	2 678	97.1	96.4–97.7	
Gold exclusively	2 115	76.7	75.1–78.2	
Coal exclusively	27	1.0	0.6–1.4	
Platinum exclusively	53	1.9	1.5–2.4	
Smoking history				
Ever smoker	1 983	72.7	71.0–74.4	
Never smoked	744	27.3	25.6–29.0	

IQR: interquartile range; CI: confidence interval

and information of interest was captured from medical records. Definitions of variables, and information on measurement techniques, and quality and completeness of the data, are provided in Table 1. Demographic and exposure characteristics included age, length of service, occupation, type of mine, and history of smoking. Clinical and disease characteristics included radiological silicosis, HIV status, history of past tuberculosis treatment, radiological change suggestive of tuberculosis, current tuberculosis status, cough, shortness of breath, oxygen saturation, body mass index (BMI), GeneXpert test result, and spirometry results (percentage predicted of FEV_1 and FVC, and of FEV_1/FVC). For purposes of describing the clinical profile of individuals with active tuberculosis, we excluded cases whose treatment commenced elsewhere, as their clinical status might have changed by the time of their visit to the Mafeteng OHSC.

The chest X-rays were read by a medical officer trained in South Africa in the International Labour Organization (ILO) radiograph system for classifying pneumoconiosis[17] and checked by two occupational medicine specialists. As silicosis is not visible on the chest X-ray in a substantial proportion of gold miners,[18] this study was concerned with radiological silicosis, defined as profusion 1/0 or greater, with or without tuberculosis, using the ILO international classification.

Permission to analyse and publish the data was provided by the Wits Health Consortium-TIMS project. Ethical clearance was issued by the Human Research Ethics Committee of the Ministry of Health of Lesotho (ID: 142-2018).

STATISTICAL ANALYSIS

Data were captured using Numbers software (version 6.2.1, Apple Inc., 2008–2019). Statistical analysis was performed using Wizard Pro 1.9.38 (wizardmac.com). Medians, interquartile ranges (IQRs)

Table 3. Disease status and clinical characteristics of ex-miners who had ever worked in gold mining (N = 2 678)

Disease	n	%	95% CI
Silicosis	1 139	42.5	40.7–44.4
HIV	817	30.7	29.0–32.5
Silicotuberculosis	688	25.7	24.0–27.4
Current active tuberculosis*	181	6.8	5.9–7.8
Current tuberculosis	75	2.8	2.2–3.5
Past history of tuberculosis	1 443	54.1	52.2–55.9
Radiological changes suggestive of tuberculosis	1 631	60.9	59.1–62.8
Clinical characteristic			
Cough	771	28.9	27.2–30.7
Shortness of breath	803	30.2	28.5–31.9
Shortness of breath at rest	35	1.3	0.9–1.8
Oxygen saturation, SpO_2, (%)			
≤ 90	79	3.3	2.7–4.2
90–94	564	23.9	22.2–25.6
≥ 95	1 718	72.8	70.9–74.5
BMI category			
Normal	1 445	57.1	55.2–59.0
Underweight	444	17.4	16.0–18.9
Overweight	486	19.1	17.6–20.6
Obese	163	6.4	5.5–7.4
FEV_1 (% predicted)			
< 60	331	15.2	13.8–16.8
60–79	419	19.2	17.6–21.0
≥ 80	1 427	65.5	63.5–67.5
FVC (% predicted)			
< 60	98	4.5	3.7–5.5
60–79	310	14.2	12.8–15.8
≥ 80	1 769	81.3	79.6–82.8
FEV_1/FVC (% predicted)			
< 60	147	6.8	5.8–7.9
60–79	403	18.5	16.9–20.2
≥ 80	1 627	74.7	72.9–76.5

**tuberculosis on treatment diagnosed elsewhere plus tuberculosis diagnosed at the OHSC*

and total ranges were used to summarise numeric variables after confirming non-normality. Frequencies and proportions with 95% confidence intervals were used to summarise categorical variables.

RESULTS

Characteristics of the study population

The demographic and occupational characteristics of the study participants (N = 2 758) are summarised in Table 2. The median age of the ex-miners was 62 years (IQR 57–68) and the median length of service was 28 years (IQR 20–34). Almost all (n = 2 678; 97.1%) had worked in gold mines at some stage, with relatively few having worked in platinum and coal mines. Most had worked exclusively in gold mines (n = 2 115; 76.7%) and in occupations classified as high dust exposure (n = 2 005; 72.7%). Ever smokers made up 72.7% (n = 1 983).

Table 3 presents the clinical outcomes of those who had worked in gold mines at any stage of their career (n = 2 678). The disease prevalences were: silicosis 42.5% (n = 1 139), HIV-positive status 30.7% (n = 817), silicotuberculosis 25.7% (n = 688), and current active tuberculosis 6.8% (n = 181). More than half (n = 1 143; 54.1%) of the participants had a history of previously treated tuberculosis. Of those with current active tuberculosis (diagnosed at the OHSC or elsewhere), the tuberculosis was recurrent in 48.1% (n = 87).

All those with tuberculosis diagnosed at the OHSC (n = 75) during the study period had worked in a gold mine at some stage in their careers. Of these, 42 (56.0%) had recurrent tuberculosis. Clinically, 41 (54.7%) had neither cough nor fever and five (6.7%) had normal chest X-rays. Of these 41, two (4.9%) screened as negative, based on symptoms and chest X-ray findings.

Of the markers of respiratory impairment at attendance, severe peripheral oxygen desaturation ($SpO_2 \leq 90\%$) was reported in 3.3% of the sample (n = 79). Spirometry outcomes were limited to percentage of predicted. The proportions of ex-miners with < 60% predicted values were: 15.2% (n = 331) for FEV_1, 4.5% (n = 98) for FVC, and 6.8% (n = 147) for FEV_1/FVC, suggesting a predominance of obstruction.

Of the 53 ex-miners who had worked exclusively in the platinum mining sector, 46.2% (n = 24) were HIV-positive, 11.3% (n = 6) had silicosis, and 5.7% (n = 3) had active tuberculosis. Among exclusive ex-coal miners (n = 27), 33.3% (n = 9) were HIV-positive and 11.1% (n = 3) had silicosis. None of the coal miners had active tuberculosis.

DISCUSSION

This report, based on data collected in the TIMS programme at the Mafeteng OHSC, reveals a very high burden of silicosis, tuberculosis, HIV and lung impairment in ex-miners living in Lesotho. It is, to our knowledge, the largest study of the burden of mining-related lung disease in living migrant former gold miners conducted in the last 50 years.

The study is timeous, given the current large-scale compensation initiatives that require information about ex-miners. Most of the research into silicosis and related tuberculosis in the South African mining industry has been conducted among in-service miners. An important exception is white ex-miners who had better access to the state examination facilities in Johannesburg until 1994 and were thus the subject of important studies published in the 1990s and beyond.[19] Although the South African compensation legislation de jure covers all eligible miners, irrespective of racial ascription or country of origin, in practice, most migrant black miners have access to the compensation system only while employed.

COMPARISON WITH OTHER STUDIES

Table 4 provides a comparison of the findings from our study with those from three previous studies of ex-miners from the South African gold mines. The most comparable study is that of Basotho ex-gold miners carried out in 2001, following a mass retrenchment at one mine.[13,14] Comparative findings are similar mean duration of service (26.9 vs 25.6 years), but older mean age (62.0 vs 49.4 years) and a higher HIV prevalence (30.7% vs 22.3%) in our study. Strikingly, the prevalence of silicosis (with or without tuberculosis) was much higher in our study (42.5% vs 24.6%), as was that of silicosis with tuberculosis (25.7% vs 10.6%). The prevalences of active tuberculosis were similar (6.8% vs 6.2%) but self-reported tuberculosis treatment was much higher in our study (54.1% vs 26%).

The higher prevalence of silicosis in our study might be partly explained by the more sensitive but less specific ILO radiological threshold that was used (≥ 1/0). A threshold of ≥ 1/1 was used in the earlier study.[13] We also restricted our analysis to those who had worked underground where dusty jobs are concentrated. However, the results are consistent with a powerful continuing cohort effect of both HIV and latency (retained silica dust in the lung) on the risk of tuberculosis post-employment, and of late appearance of

Table 4. Summary of prevalence studies on silicosis and tuberculosis in South African ex-gold miners

Author, year	Year of study	Place	N	Mean age (years)	Mean years in mining	Silicosis (%)	TB (past treatment, TB on CXR) (%)	Silicosis + TB (%)	Active TB (%)	HIV-positive (%)
Steen *et al*, 1998[23]	1997	Thamaga, Botswana	234*	56	14.6	26.6; 31†	29 (past treatment) 24 (CXR)		1.7‡	
Trapido *et al*, 1998[24]	1994	Libode, Transkei	288	53	12.15	22; 36§	51 (past treatment) ‖ 33; 47 (CXR) §			
Girdler-Brown *et al*, 2008[13]	2001–2002	Lesotho	610	49	25.6	24.6¶ (4 readers)	26 (past treatment)	11**	6.2	22.3
This study, 2020	2017–2018	Lesotho	2 678	62	28.0	42.5†† (1 reader)	54 (past treatment) 61 (CXR)	26	6.8	30.7

*CXR: chest X-ray; *underground gold miner subgroup; † ILO profusion >1/0 (prevalences from both readers); ‡ 4 new tuberculosis cases (using 234 as denominator); § ILO profusion ≥ 1/0 (prevalences from both readers); ‖ reported in White et al., 2001[27]; ¶ ILO profusion ≥ 1/1 (prevalence from reader with 'best overall agreement'); **calculated from Figure 2; †† ILO profusion ≥ 1/0*

radiological silicosis.[18,20] In addition, ageing has been shown to be a strong independent risk factor for active tuberculosis in gold miners [21] and has also been associated with increased silicosis frequency at autopsy, independently of duration of exposure.[22]

Compared to the ex-gold miner studies conducted in the 1990s,[23,24] the miners in our study had a slightly higher mean age, but a considerably higher mean duration of exposure, prevalence of silicosis, active tuberculosis, and silicosis combined with tuberculosis. Both of the earlier studies had less restrictive inclusion criteria which would have reduced observed disease prevalence because of the inclusion of lower risk and asymptomatic ex-workers. The effect of a higher HIV prevalence in the current cohort than those studied in the mid-1990s would have further contributed to the current excess burden of tuberculosis.[21]

Finally, there is information from two samples of ex-miners examined specifically for compensation purposes. In a study of 300 ex-gold miners in the (former) Transkei, conducted from 1997 to 1999, the prevalence of radiological silicosis (threshold undefined) was 33.4%.[25] The prevalence of silicosis combined with tuberculosis (presumably radiological) was 28.4%. More recently, the Q(h)ubeka Trust, formed following a silicosis lawsuit settlement, had examined 3 519 ex-gold miners by 30 April 2020.[7] The calculated prevalence of compensable disease (silicosis ≥ ILO 1/0 with or without lung function loss and/or radiological signs of past or current tuberculosis) was 55.7%. The findings from our study are comparable with those from these two studies.

The numbers of exclusive platinum and coal ex-miners were small. Silicosis is a component of coal mine dust lung disease[26] but is uncommon in platinum miners.[28] Cases of silicosis were found in both groups, together with high prevalences of HIV. This indicates that ex-platinum and ex-coal miners, who are covered by the ODMWA, should be included in programmes aimed at improving access to BMEs.

IMPLICATIONS

From 1973 to 2012, the number of miners from Lesotho was of the order of 190 000, and represented 12.6% of all new entrants into the South African mining industry recruited via TEBA.[11] While the proportion of miners from Lesotho declined from the 1970s to the 1990s, the actual number of individuals from Lesotho increased with the large-scale increase in employment. Since 1988, total gold mining employment has been declining, reaching approximately 98 000 in September 2019.[11,29] As a result, the ex-gold miner population now greatly outnumbers the active miner population. It is difficult to estimate the number of living ex-miners in Lesotho but, assuming that 60% of the total recruited cohort are still alive, and allowing for the fact that not all worked in the gold mining industry, and that some may have taken South African citizenship after 1994,[30] the number of ex-gold miners in Lesotho could be around 95 000.

The public health implications of these findings are profound. Silicosis is a chronic disease associated with lung function impairment at higher grades of severity, but the most serious impact of silicosis on public health in this setting is that it greatly increases the risk of tuberculosis.[31] When silicosis occurs together with HIV, the increased relative risk of tuberculosis (compared to miners with neither condition) is 16-fold.[32] Even if successfully treated, it is now appreciated that tuberculosis has significant chronic post-treatment sequelae.[33,34] In this sample of gold miners, the features of chronic respiratory ill-health included lung function impairment (mainly obstruction) and chronic hypoxaemia, which should entail assessment for oxygen supplementation.[35] The high burden of mining-related disease among ex-miners has thus imposed a substantial public health burden on the health system, social structure and economy of this small, low-income country.

The findings also have a number of implications for the current outreach compensation programmes for ex-gold miners. First, the prevalence of silicosis, at least in long-service ex-gold miners, is very high. In this study, although all chest images read as ILO 1/0 or greater are reported as silicosis, some proportion would not meet the criteria for first-degree compensation (i.e. without tuberculosis) used by the Medical Bureau for Occupational Diseases (MBOD) or the Tshiamiso Trust.

Second, this group has a very high prevalence of tuberculosis – active and past. Tuberculosis on its own, occurring 12 months or more after leaving employment, is not compensable under either the ODMWA or the Tshiamiso Trust deed. However, a large proportion of ex-gold miners with silicosis (25.7%) had evidence of old tuberculosis fibrosis on the X-ray and/or active tuberculosis, i.e. silicotuberculosis. The radiological distinction between the two diseases, silicosis and tuberculosis, individually, and combined disease, requires specific expertise and experience,[36,37] and the final criteria for compensation purposes may well differ from the readings in this study. Nevertheless, it is likely that a large proportion of claimants will qualify for the second-degree category of silicosis plus tuberculosis under the ODMWA and/or for Silicosis Class 3 under the Tshiamiso Trust deed.

Finally, the high prevalences of active tuberculosis (6.8%), some of which was undiagnosed at the time of the visit, and HIV (30.7%) in these ex- gold miners, place a particular responsibility on any compensation programme and health service, whether public or private/corporate, to screen for both of these diseases in this population, and to refer those found to be positive to local health services. This creates a corresponding demand on these health services to offer the necessary early diagnosis, treatment, care and follow up.

STRENGTHS AND LIMITATIONS

The strengths of this study are the large sample and consistency in collection of data from a single clinical centre. GeneXpert tuberculosis testing was carried out on almost all participants and HIV status was based on history or test results. This has, to our knowledge, not been achieved in any previous study of ex-miners.

A limitation is that information was collected as part of a clinical screening programme rather than for research purposes. The chest X-rays were read by a single reader and a sample was reread by two occupational medicine specialists. Given the well-established differences between readers using the ILO system,[28] it is possible that, for example, a B-reader would have given different silicosis judgements. If such differential readings were random, this would not necessarily have produced a substantially different prevalence of silicosis.[28] However, bias in reliance on a single reader cannot be excluded.

Although spirometric volumes were recorded at the clinic visit, only percentages of predicted values were captured into the database. As a result, the calculation of the prevalence and degree of impairment did not include the FEV_1/FVC ratio. Similarly, as duration of mine service but not calendar dates were captured, disease latency could not be analysed.

Ex-miners who presented for screening were aware of the screening programme, possible benefits of treatment or compensation, or

both, and were able to access the centres from different parts of the country. Miners with ill-health or long mining service might have been more motivated to attend than healthy miners or those with shorter service. This would have resulted in higher proportions of disease than would be calculated in a random sample, which would have included more short-service and asymptomatic workers. Miners identified as very ill during the mobilisation campaigns were referred directly to local health services and thus may not have reached the OHSCs. With only two OHSCs serving the whole of Lesotho, many ex-miners had to travel long distances to reach these facilities. Modes of transport included those that were self-organised or via civil society organisations working with TIMS. Poor access to health services thus limits generalisability of the findings to all parts of the country.

CONCLUSION

We sought to add information about the extent of mining-related diseases among migrant ex-gold miners, specifically, to that collected previously in Basotho miners, Botswana, and the Eastern Cape. This information should be useful to current compensation initiatives in implementing programmes for clinical assessment of silicosis and tuberculosis, claims management and payment. In this regard, the large databases of medical assessments of claims of ex-miners, conducted within the TIMS programme and by compensation trusts, present an opportunity to better understand the burden of disease and healthcare needs of this population, and to fill gaps in our knowledge.

The findings confirm the continuing triple epidemic of silicosis, tuberculosis and HIV, affecting ex-miners in Lesotho,[31,38,39] and the need for a public health plan and resources to continue to screen ex-miners and their families for these diseases, and to provide the necessary curative and supportive treatment. The call on mining companies, the health systems in the affected countries, regional and international agencies, and civil society organisations to coordinate action and find resources to prevent and mitigate the suffering of these ex-miners, remains urgent.

LESSONS LEARNED

1. Among migrant ex-gold miners from the South African mines living in Lesotho, there is a high burden of silicosis and tuberculosis, including undiagnosed and asymptomatic disease, HIV infection and associated respiratory impairment.
2. There is a need to train local medical care providers in diagnosis and management of these combined and overlapping diseases, e.g. in distinguishing silicosis from tuberculosis, and obstruction due to dust exposure or previous tuberculosis from asthma.
3. Screening and compensation programmes should make provision for maintenance of accurate and accessible databases of occupational and clinical information for research purposes.

DECLARATION

Dr Maboso worked as on-site doctor at Mafeteng OHSC from January 2017 to December 2019 under the TIMS project. Dr Barnes has worked for a number of mining companies, providing occupational health guidance, assurance and technical support, and has provided input required to prepare for legal action. He was directly involved in the establishment and operation of the Mafeteng OHSC and 10 other OHSCs established by the Wits Health Consortium, for the Global Fund, across the Southern African Development Community. Prof. Ehrlich has previously written expert reports on silicosis for plaintiff attorneys in litigation.

ACKNOWLEDGMENTS

The authors thank the Tuberculosis in the Mining Sector in Southern Africa (TIMS) project for the authorisation to use the data. We also thank all the TIMS Mafeteng OHSC staff for their steadfast work in collecting the data used in the writing of this paper. We acknowledge Mr Makoae Mathaha for his efforts in double-checking the data analysis. We thank Dr Riedawaan Pillay, TIMS programme manager, for his support.

FUNDING

The health centre and its activities fell within the TIMS project funding. There was no external additional funding for this analysis or the write-up.

AUTHOR CONTRIBUTIONS

Conception and design of the study: BMM
Data acquisition: BMM
Data analysis: BMM, KMM
Interpretation of the data: BMM, RE, KMM
Drafting of the paper: BMM, RE, LBM, SJM, ML
Critical revision of the paper: RE, DM, VG, KMM, DFB

REFERENCES

1. TB in the Mining Sector in Southern Africa (TIMS). July 16, 2019. Available from: https://www.timssa.co.za/Whoweare/AboutTIMS.aspx (accessed 31 Jan 2020).
2. The Southern African Development Community. Protocol on mining in the Southern African Development Community (SADC). SADC; 2006. Available from: https://www.sadc.int/files/3313/5292/8366/Protocol_on_Mining.pdf (accessed 8 Feb 2020).
3. The Southern African Development Community. Declaration on tuberculosis in the mining sector. SADC; 2012. Available from: http://www.stoptb.org/assets/documents/news/Declaration%20on%20Tuberculosis%20in%20the%20Mining%20Sector2012English.pdf (accessed 23 Jul 2020).
4. Gonzales LL. SADC to harmonise TB treatment, cross-border referrals. Health-E News. 2014 March 26. Available from: https://health-e.org.za/2014/03/26/sadc-harmonise-tb-treatment-cross-border-referrals/ (accessed 12 Feb 2020).
5. Settlement of the silicosis and TB class action; 2020. Available from: https://www.silicosissettlement.co.za/about (accessed 23 Jul 2020).
6. Anglo American settles silicosis suit. Times Live. 2013 Sep 25. Available from: https://www.timeslive.co.za/news/south-africa/2013-09-25-anglo-american-settles-silicosis-suit/ (accessed 31 Jan 2020).
7. Q(h)ubeka Trust; undated. Available from: https://www.qhubekatrust.co.za/ (accessed 31 Jan 2020).
8. Ehrlich RI. A century of miners' compensation in South Africa. Am J Ind Med. 2012; 55:560-569.
9. Kistnasamy B, Yassi A, Yu J, Spiegel SJ, Fourie A, Barker S, et al. Tackling injustices of occupational lung disease acquired in South African mines: recent

developments and ongoing challenges. Global Health. 2018; 14:60. Available from: https://doi.org/10.1186/s12992-018-0376-3 (accessed 23 Jul 2020).
10. Lesotho population. Countrymeters; 2020. Available from: https://countrymeters.info/en/Lesotho (accessed 6 Feb 2020).
11. Ehrlich RI, Montgomery A, Akugizibwe P, Gonsalves G. Public health implications of changing patterns of recruitment into the South African mining industry, 1973-2012: a database analysis. BMC Public Health. 2017; 18(1). DOI: 10.1186/s12889-017-4640-x.
12. Budiaki L. Tuberculosis and compensation: a study of a selection of Basotho mineworkers from Maseru district [MPH dissertation]. Johannesburg: University of the Witwatersrand; 2004. Available from: https://pdfs.semanticscholar.org/1d44/925df55308739f17adb86ffab1205f34efea.pdf (accessed 31 Jan 2020).
13. Girdler-Brown BV, White NW, Ehrlich RI, Churchyard GJ. The burden of silicosis, pulmonary tuberculosis and COPD among former Basotho goldminers. Am J Ind Med. 2008; 51:640-647.
14. Park HH, Girdler-Brown BV, Churchyard GJ, White NW, Ehrlich RI. Incidence of tuberculosis and HIV and progression of silicosis and lung function impairment among former Basotho gold miners. Am J Ind Med. 2009; 52:901-908.
15. UNAIDS Data 2019. UNAIDS; undated. Available from: https://www.unaids.org/sites/default/files/media_asset/2019-UNAIDS-data_en.pdf (accessed 6 Feb 2020).
16. World Health Organization. Global tuberculosis report 2019. Geneva: WHO; 2019. Available from: https://apps.who.int/iris/bitstream/handle/10665/329368/9789241565714-eng.pdf?ua=1 (accessed 6 Feb 2020).
17. International Labour Organization. Guidelines for the use of the ILO International Classification of Radiographs of Pneumoconioses, revised edition 2011. Available from: https://www.ilo.org/safework/info/publications/WCMS_168260/lang--en/index.htm safework/documents/publication/wcms_168260.pdf (accessed 23 Jul 2020).
18. Ehrlich R, Murray J, Rees D. Subradiological silicosis. Am J Ind Med. 2018; 61(11):877-885.
19. Hnizdo E, Sluis-Cremer GK. Risk of silicosis in a cohort of white South African gold miners. Am J Ind Med. 1993; 24:447-457.
20. Hnizdo E, Murray J. Risk of pulmonary tuberculosis relative to silicosis and exposure to dust in South African gold miners. Occup Environ Med. 1998; 55(7):496-502.
21. Kleinschmidt I, Churchyard G. Variation in incidences of tuberculosis in subgroups of South African gold miners. Occup Environ Med. 1997; 54:636-641.
22. Nelson G, Girdler-Brown B, Ndlovu N, Murray J. Three decades of silicosis: disease trends at autopsy in South African gold miners. Environ Health Perspect. 2010; 118 (3):421-426.
23. Steen TW, Gyi KM, White NW, Gabosianelwe T, Ludick S, Mazonde GN, et al. Prevalence of occupational lung disease among Botswana men formerly employed in the South African mining industry. Occup Environ Med.1997; 54(1):19-26.
24. Trapido AS, Mqoqi NP, Williams BG, White N, Brian G, Salomon A et al. Prevalence of occupational lung disease in a random sample of former mineworkers, Libode District, Eastern Cape Province, South Africa. Am J Ind Med. 1998: 34:305-313.
25. Meel B. Patterns of lung diseases in former mine workers of the former Republic of the Transkei: an X-ray-based study. Int J Occup Environ Health. 2002; 8(2):105-110.
26. Petsonk EL, Rose C, Cohen R. Coal mine dust lung disease. New lessons from an old exposure. Am J Respir Crit Care Med. 2013; 187(11):1178-1185.
27. White NW, Steen TW, Trapido ASM, Davies JCA, Mabongo NM, Monare N, et al. Occupational lung diseases among former goldminers in two labour sending areas. S Afr Med J. 2001; 91:599-604.
28. Nelson G, Murray J. Silicosis at autopsy in platinum mine workers. Occup Med. 2013; 63:196-202.
29. South African Market Insights. Employment in South Africa's gold mining industry over time. South African Market Insights. 2019 Jan 10. Available from: https://www.southafricanmi.com/employment-gold-mining-10jan2019.html (accessed 31 Jan 2020).
30. Simelane X, Modisha G. From formal to informal migrant labour system: the impact of the changing nature of the migrant labour system on mining communities in Lesotho and Mozambique. Paper presented at: XIV South African Sociological Association (SASA) Congress; 7-10 Jul 2008; Stellenbosch, South Africa. Available from: http://www.hsrc.ac.za/en/research-outputs/view/4226 (accessed 31 Jan 2020).
31. Akugizibwe P. Systematic review of the association and dose-response and relationship between silica exposure or silicosis, and risk of TB disease and TB mortality [MPH dissertation]. Cape Town: University of Cape Town; 2014. Available from: http://hdl.handle.net/11427/6019 (accessed 12 Feb 2020).
32. Corbett EL, Churchyard GJ, Clayton TC, Williams BG, Mulder D, Hayes RJ, et al. HIV infection and silicosis: the impact of two potent risk factors on the incidence of mycobacterial disease in South African miners. AIDS. 2000; 14(17):2759-2768.
33. Ehrlich RI, Adams S, Baatjies R, Jeebhay MF. Chronic airflow obstruction and respiratory symptoms following tuberculosis: a review of South African studies. Int J Tuberc Lung Dis. 2011; 15(7):886-891.
34. Romanowski K, Baumann B, Basham CA, Khan FA, Fox GJ, Johnston JC. Long-term all-cause mortality in people treated for tuberculosis: a systematic review and meta-analysis. Lancet Infect Dis. 2019; 19(10):1129-1137.
35. Kida K, Motegi T, Ishii T, Hattori K. Long-term oxygen therapy in Japan: history, present status, and current problems. Pneumonol Alergol Pol. 2013; 81:468-478.
36. Franzblau A, teWaterNaude J, Sen A, d'Arcy H, Smilg JS, Mashao KS, et al. Comparison of digital and film chest radiography for detection and medical surveillance of silicosis in a setting with a high burden of tuberculosis. Am Ind Med. 2018; 61(3):229-238.
37. Solomon A. Silicosis and tuberculosis: part 2 – a radiographic presentation of nodular tuberculosis and silicosis. Int J Occup Environ Health. 2001; 7:54-57.
38. Churchyard GJ, Ehrlich R, teWaterNaude JM, Pemba L, Dekker K, Vermeijs M, et al. Silicosis prevalence and exposure-response relations in South African goldminers. Occup Environ Med. 2004; 61:811-816.
39. Knight D, Ehrlich RI, Fielding K, Jeffery H, Grant A, Churchyard G. Trends in silicosis prevalence and the healthy worker effect among active gold miners in South Africa: a prevalence study with follow up of employment status. BMC Public Health. 2015; 15:1258. DOI: 10.1186/s12889-015-2566-8.