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PREVALENCE AND FACTORS ASSOCIATED WITH SILICOSIS AMONG MINES WORKERS OF RUTONGO MINES INDUSTRY, IN RWANDA

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Abstract
Silicosis, an occupational lung disease, remains a significant public health issue worldwide. The disease disproportionately affects workers in various industries, particularly mining. Globally, an estimated 2.4 million workers are exposed to silica dust, making silicosis a substantial contributor to work-related respiratory illnesses. While the mining sector plays a vital role in economic development, it also exposes workers to serious health risks, especially through prolonged inhalation of respirable silica dust. In Rwanda, workers at Rutongo Mines are regularly involved in activities such as drilling and blasting, placing them at high risk of silicosis. Despite these known risks, no comprehensive study had previously assessed the burden of silicosis in this workforce. The objectives of this study were to determine the prevalence and factors associated with silicosis among mine workers of Rutongo mines industry, Rwanda.

This study employed a cross-sectional quantitative design, targeting employees of Rutongo Mines Industry. Out of a total population of 1,015 workers, a sample of 316 participants was selected using Yamane's formula. Data were collected using structured questionnaires and secondary records from Rutongo District Hospital. Analyses were performed using univariate, bivariate, and multivariate statistical methods, and results were presented in tables and figures. The study revealed that 10.1% of mine workers were diagnosed with silicosis. Significant factors associated with silicosis included age above 50 years (AOR=4.5), undergrounds mining (AOR = 4.021), HIV-positive status (AOR=9.3), previous TB treatment (AOR=4.9), positive COVID-19 test (AOR=3.9), smoking (AOR=2.7), and long-term exposure of 15+ years (AOR=5.7). The findings highlight a moderate but concerning burden of silicosis and underscore the urgent need for improved occupational health practices and respiratory protection interventions in the mining sector. In conclusion, the study demonstrated that silicosis remains a pressing occupational health concern in Rutongo Mines, driven by both personal and work-related factors. The results call for strengthened health surveillance, dust exposure control, and targeted education for high-risk workers. Ethical approval was obtained from Mount Kenya University, and all participants gave informed consent.

Introduction

Silicosis is one of the most serious occupational diseases, with increasing cases around the world and is the most common concerns for mines workers. (Rupani; 2023). Respirable crystalline silica (RCS) consists of tiny particles less than 10 micrometres in diameter and is commonly generated, or entrained into the air, during mining operations and in a variety of industries including construction work, quarrying, stone cutting, and hydraulic fracturing. Mining activities has a well-established association with silicosis. Globally, an estimated 2.4 million workers are exposed to silica dust, making silicosis a substantial contributor to work-related respiratory illnesses. The current global prevalence of silicosis is not well defined, due to limited and/or absent screening programs in many low- and middle-income countries.

Silicosis has been on the agendas of the International Labour Organization (ILO) and World Health Organization (WHO) and remains an urgent public health issue. While the mining sector plays a vital role in economic development, it also exposes workers to serious health risks, especially through prolonged inhalation of respirable silica dust. In Rwanda, workers at Rutongo Mines are regularly involved in activities such as drilling and blasting, placing them at high risk of silicosis. Despite these known risks, no comprehensive study had previously assessed the burden of silicosis in this workforce. The objectives of this study were to determine the prevalence and factors associated with silicosis among mine workers of Rutongo mines industry, Rwanda.

Methods:

Study Setting: Data were collected using structured Data capture sheet on patients records from Rutongo District Hospital attended a screening test conducted in 2023. Rutongo mines industry is located in Rulindo District, Northern province of Rwanda; within Rutongo District Hospital Catchment area.

Study Design and Population

This study employed a cross-sectional quantitative design, targeting employees of Rutongo Mines Industry who underwent a screening test by Rutongo District hospital between March and May 2023. Out of a total population of 1,015 workers Tested using In-person data collection, consisting of a questionnaire and chest radiograph. Participation were entirely voluntally. A sample of 316 participants was selected using Yamane's formula. A researcher designed an instrument to collect information on demographics; post occupied; common silicosis symptoms; exposures and risks factors for silicosis, including mine employment history; and past medical history and result of screening tests (Appendix). Questions on silicosis risk factors were derived from an existing questionnaire used for silicosis screening.

Statistical Analysis

The secondary data collected from Rutongo District Hospital was processed promptly, including steps such as coding, cleaning, and tabulating. SPSS was utilized for efficient data management. Descriptive analysis was conducted on quantitative data to report frequencies and percentages, including the prevalence of silicosis and non-silicosis among mine workers. Silicosis diagnosis was classified as either positive (presence of silicosis) or negative (absence of silicosis) based on radiological findings. Descriptive analysis was performed through univariate analysis to summarize key variables such as demographic characteristics, occupational exposure, and health conditions. This was followed by bivariate analysis using Chi-square tests to explore associations between independent variables (e.g., age, exposure duration, use of PPE) and the presence or absence of silicosis. Significant variables identified through bivariate analysis were adjusted using logistic regression analysis to assess their independent effect on the likelihood of developing silicosis. A p-value of less than 0.05 was considered statistically significant, and the results were interpreted within a 95% confidence interval. The analysis focused on the employee dimension to enhance understanding of occupational health risks and inform interventions for mine workers.

The data was presented in tables and figures appropriately. Further interpreted to render it more meaningful by explaining the results and comparing them to the reviewed literature.

Results:

Socio-demographic Characteristics of the Respondents, n=316

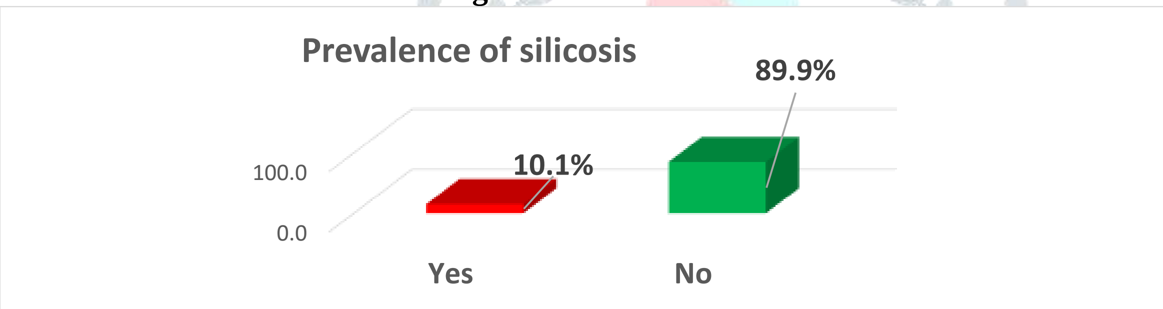
Variables	Frequency	Percentage
Gender		
Male	302	95.6
Female	14	4.4
Age		
Young Adults (18–34 years)	110	34.8
Middle-Aged Adults (35–49 years)	155	49.1
Older Adults (50 years and above)	51	16.1
Education		
Primary	75	23.7
Tertiary	112	35.4
No formal education	23	7.3
Secondary	106	33.5
Marital status		
Single	261	82.6
Married	55	17.4

Occupation		
Underground miner	222	70.3
Technician	80	25.3
Security	9	2.8
Timber	2	0.6
Mechanic	1	0.3
Administration	2	0.6
Health insurance		
MUSA	232	73.4
RSSB	84	26.6
Residence		
Urban	4	1.3
Rural	312	98.7

The sample was predominantly male (95.6%), with only 4.4% female participants, reflecting the male-dominated nature of the mining sector. In terms of age distribution, nearly half of the respondents (49.1%) were middle-aged adults (35–49 years), followed by young adults (18–34 years) who made up 34.8%, and older adults (50 years and above) comprising 16.1%. Regarding education level, 35.4% of the workers had attained tertiary education, while 33.5% had secondary education. A smaller portion, 23.7%, had only primary education, and 7.3% had no formal education. With respect to marital status, most participants were single (82.6%), and only 17.4% were married.

Occupationally, the largest group was underground miners (70.3%), followed by technicians (25.3%). The remaining respondents held roles in security (2.8%), timber handling (0.6%), mechanical work (0.3%), and administration (0.6%). In terms of health insurance coverage, 73.4% were covered under MUSA (Mutuelle de Santé), while 26.6% were enrolled in the Rwanda Social Security Board (RSSB) scheme. Lastly, 98.7% of the respondents resided in rural areas, while only 1.3% lived in urban areas.

4.2 Presentation of the findings



The findings presented in Figure 4.1 highlight the silicosis status among mine workers of Rutongo Mines Industry, revealing that 10.1% of the participants were diagnosed with silicosis while 89.9% were not.

Factors associated with silicosis among mine workers of Rutongo Mines Industry

Variables	Frequency	Percentage
Cough		
Yes	34	10.8
No	282	89.2
Entry Age (Age at which you started working at Rutongo Mines)		
Early Starters: 15–24 years	104	32.9
Mid-Age Starters: 25–34 years	123	38.9
Late Starters: 35 years and above	89	28.2
Time of Exposure (Duration of employment at Rutongo Mines)		
Short-Term Exposure: Less than 5 years	72	22.8
Medium-Term Exposure: 5–14 years	184	58.2
Long-Term Exposure: 15 years and above	60	19.0
Previous Positive COVID-19 Test		
Yes	3	.9
No	313	99.1
HIV Status		
Positive	4	1.3
Negative	312	98.7
Tobacco smoking		
Yes	28	8.9

No	288	91.1
Comorbidity		
Yes	5	1.6
No	311	98.4
Previous TB treatment		
Yes	3	.9
No	313	99.1
Other symptoms (chest pain, chronic cough, shortness of breath; bloody sputum)		
Yes	22	7.0
No	294	93.0

The data show that 10.8% of the participants reported experiencing a cough, while 89.2% reported no cough. In terms of entry age, 32.9% of the workers started working at Rutongo Mines between the ages of 15–24 years (early starters), 38.9% between 25–34 years (mid-age starters), and 28.2% began at 35 years or older (late starters).

Regarding duration of employment, the majority of workers (58.2%) had been employed for 5–14 years (medium-term exposure), followed by 22.8% with less than 5 years (short-term exposure), and 19.0% with 15 years or more of employment (long-term exposure). Only a small percentage of workers (0.9%) reported a previous positive COVID-19 test, and 1.3% were HIV-positive.

Tobacco smoking was reported by 8.9% of respondents, while the vast majority (91.1%) were non-smokers. Likewise, comorbidities other than HIV and TB were rare, with only 1.6% of participants reporting any. Previous TB treatment was also uncommon, with only 0.9% of workers reporting a past history of TB. However, 7.0% of workers reported other respiratory symptoms, such as chest pain, chronic cough, shortness of breath, or bloody sputum.

Procedure-related factors, n=316

Variables	Frequency	Percentage
Working in Dust-Containing Crystalline Silica		
Yes	221	69.9
No	95	30.1
Working Without Facial Masks and Other Personal Protective Equipment (PPE)		
Yes	0	0.0
No	316	100.0
Working shift time: More than 8 hours		
Yes	309	97.8
No	7	2.2

Source: Primary data, 2025

The data show that a majority of workers (69.9%) reported working in environments containing crystalline silica dust, while 30.1% worked in areas without direct exposure to such dust. None of the workers (0.0%) reported working without facial masks or other personal protective equipment (PPE), indicating universal compliance with PPE use policies. In terms of working hours, almost all respondents (97.8%) reported working more than 8 hours per shift, while only 2.2% worked 8 hours or less.

Bivariate analysis of socio-demographic factors associated with silicosis among mine workers of Rutongo Mines Industry

Particulars	Silicosis		Chi-square	P-value
	Yes n(%)	No n(%)		
Gender			0.143	0.705
Male	31(10.3)	271(89.7)		
Female	1(7.1)	13(92.9)		
Age			7.310	**0.026**
Young Adults (18–34 years)	5(4.5)	105(95.5)		
Middle-Aged Adults (35–49 years)	18(11.6)	137(88.4)		
Older Adults (50 years and above)	9(17.6)	42(82.4)		
Education			9.189	**0.027**
Primary	14(18.7)	61(81.3)		
No formal education	11(9.8)	101(90.2)		
Tertiary	1(4.3)	22(95.7)		
Secondary	6(5.7)	100(94.3)		
Marital status			3.082	0.079
Single	30(11.5)	231(88.5)		
Married	2(3.6)	53(96.4)		
Occupation			12.095	0.034
Underground miner	31(14.0)	191(86.0)		
Technician	1(1.2)	79(98.8)		
Security	0(0.0)	9(100)		
Timber	0(0.0)	2(100)		
Mechanic	0(0.0)	1(100)		
Administration	0(0.0)	2(100)		
Health insurance			2.190	0.139
MUSA	27(11.6)	205(88.4)		
RSSB	5(6.0)	79(94.0)		
Residence			0.456	0.499
Urban	0(0.0)	4(100)		
Rural	32(10.3)	280(89.7)		
Total=316				

Source: Primary data, 2025

The bivariate analysis revealed that age was significantly associated with silicosis ($\chi^2 = 7.310, p = 0.026$). The prevalence of silicosis increased with age: only 4.5% of young adults (18–34 years) were affected compared to 11.6% of middle-aged adults (35–49 years) and 17.6% of older adults (50 years and above). Education level also showed a statistically significant association with silicosis ($\chi^2 = 9.189$, $p = 0.027$). The highest prevalence was observed among those with only primary education (18.7%), followed by those with no formal education (9.8%). The bivariate analysis also revealed a statistically significant association between occupation and the presence of silicosis (Chi-square = 12.095, p = 0.034). The highest prevalence of silicosis was observed among underground miners, with 14.0% (31 out of 222) affected, while none of the workers in security, timber, mechanic, and administration roles had silicosis. Only 1.2% of technicians were affected. In contrast, gender, marital status, health insurance, and residence showed no significant relationship in this analysis.

Bivariate analysis of personal factors associated with silicosis among mine workers of Rutongo Mines Industry

Particulars	Silicosis		Chi-square	P-value
	Yes n(%)	No n(%)		
Cough			40.359	**0.001**
Yes	14(41.2)	20(58.8)		
No	18(6.4)	264(93.6)		
Entry Age (Age at which you started working at Rutongo Mines)			0.373	0.830
Early Starters: 15–24 years	12(11.5)	92(88.5)		
Mid-Age Starters: 25–34 years	12(9.8)	111(90.2)		
Late Starters: 35 years and above	8(9.0)	81(91.0)		
Time of Exposure (Duration of employment at Rutongo Mines)			81.775	**0.001**
Short-Term Exposure: Less than 5 years	1(1.4)	71(98.6)		
Medium-Term Exposure: 5–14 years	7(3.8)	177(96.2)		
Long-Term Exposure: 15 years and above	25(41.7)	35(58.3)		
Previous Positive COVID-19 Test			10.639	**0.001**
Yes	2(66.7)	1(33.3)		
No	30(9.6)	283(90.4)		
HIV Status			17.734	**0.001**
Positive	3(75.0)	1(25.0)		
Negative	29(9.3)	283(90.7)		
Tobacco smoking			4.312	**0.038**
Yes	6(21.4)	22(78.6)		
No	26(9.0)	262(91.0)		
Comorbidity			0.572	0.449
Yes	0(0.0)	5(100)		
No	32(10.3)	279(89.7)		
Previous TB treatment			10.639	**0.001**
Yes	2(66.7)	1(33.3)		
No	30(9.6)	283(90.4)		
Other symptoms (chest pain, chronic cough, shortness of breath; bloody sputum)			24.619	**0.001**
Yes	9(40.9)	13(59.1)		
No	23(7.8)	271(92.2)		
Total=316				

The bivariate analysis revealed that the presence of cough was strongly linked with silicosis. Among workers who reported a cough, 41.2% were found to have silicosis compared to only 6.4% of those without a cough. This difference was highly significant ($\chi^2 = 40.359$, $p = 0.001$). Time of exposure also showed a significant association with silicosis prevalence. Workers with long-term exposure (15 years and above) had the highest prevalence at 41.7%, compared to 3.8% among those with 5–14 years of exposure, and just 1.4% among those with less than 5 years of exposure. The relationship was statistically significant ($\chi^2 = 81.775$, $p = 0.001$).

Additionally, previous positive COVID-19 test was significantly associated with silicosis ($\chi^2 = 10.639$, $p = 0.001$). Among those who had tested positive for COVID-19, 66.7% were diagnosed with silicosis, compared to 9.6% among those without a known COVID-19 infection.

Similarly, HIV-positive miners were more likely to have silicosis (75%) than their HIV-negative counterparts (9.3%), with the difference being highly significant ($\chi^2 = 17.734$, $p = 0.001$).

Tobacco smoking was also significantly associated with silicosis ($\chi^2 = 4.312$, $p = 0.038$). The prevalence among smokers was 21.4%, compared to 9.0% among non-smokers. History of tuberculosis (TB) treatment showed a statistically significant relationship as well ($\chi^2 = 10.639$, $p = 0.001$), with 66.7% of those previously treated for TB having silicosis compared to only 9.6% of those without a TB history. Moreover, workers reporting other respiratory symptoms such as chest pain, shortness of breath, or bloody sputum were significantly more likely to have silicosis (40.9%) compared to those without such symptoms (7.8%), with $\chi^2 = 24.619$ and $p = 0.001$.

On the other hand, some personal factors showed no statistically significant association with silicosis. These included entry age (whether the worker started at 15–24, 25–34, or 35+ years; $\chi^2 = 0.373$, $p = 0.830$) and presence of comorbidities other than HIV or TB ($\chi^2 = 0.572$, $p = 0.449$).

Bivariate analysis of procedure-related factors associated with silicosis among mine workers of Rutongo Mines Industry

Particulars	Silicosis		Chi-square	P-value
	Yes n(%)	**No n(%)**		
Cough			40.359	**0.001**
Yes	14(41.2)	20(58.8)		
No	18(6.4)	264(93.6)		
Entry Age (Age at which you started working at Rutongo Mines)			0.373	0.830
Early Starters: 15–24 years	12(11.5)	92(88.5)		
Mid-Age Starters: 25–34 years	12(9.8)	111(90.2)		
Late Starters: 35 years and above	8(9.0)	81(91.0)		
Time of Exposure (Duration of employment at Rutongo Mines)			81.775	**0.001**
Short-Term Exposure: Less than 5 years	1(1.4)	71(98.6)		
Medium-Term Exposure: 5–14 years	7(3.8)	177(96.2)		
Long-Term Exposure: 15 years and above	25(41.7)	35(58.3)		
Previous Positive COVID-19 Test			10.639	**0.001**
Yes	2(66.7)	1(33.3)		
No	30(9.6)	283(90.4)		
HIV Status			17.734	**0.001**
Positive	3(75.0)	1(25.0)		
Negative	29(9.3)	283(90.7)		
Tobacco smoking			4.312	**0.038**
Yes	6(21.4)	22(78.6)		
No	26(9.0)	262(91.0)		
Comorbidity			0.572	0.449
Yes	0(0.0)	5(100)		
No	32(10.3)	279(89.7)		
Previous TB treatment			10.639	**0.001**
Yes	2(66.7)	1(33.3)		
No	30(9.6)	283(90.4)		
Other symptoms (chest pain, chronic cough, shortness of breath; bloody sputum)			24.619	**0.001**
Yes	9(40.9)	13(59.1)		
No	23(7.8)	271(92.2)		
Total=316				

Source: Primary data, 2025

The bivariate analysis showed that, first, regular work in areas containing crystalline-silica dust was clearly associated with disease: 13.1 % of exposed workers (29/221) had radiological evidence of silicosis versus only 3.2 % of those assigned to dust-free areas (3/95). The difference was significant ($\chi^2 = 7.25$, $p = 0.007$). Second, shift length showed a significant association with silicosis (Chi-square = 8.426, $p = 0.025$). Workers who reported working more than 8 hours per shift had a higher prevalence of silicosis, with 10.3% (31 out of 301) affected, compared to only 6.7% (1 out of 15) among those working 8 hours or less.

Multivariate analysis of factors associated with silicosis among mine workers of Rutongo Mines Industry

Particulars	AOR	95% C.I		P-value
		Lower	Upper	
Age				
Young Adults (18–34 years)	Ref.			
Middle-Aged Adults (35–49 years)	1.631	0.682	3.899	0.271
Older Adults (50 years and above)	4.500	1.424	14.216	0.010
Education				
No formal education or primary	2.107	0.900	4.936	0.009
Secondary and tertiary	Ref.			
Occupation				
Underground miners	4.021	1.841	8.524	0.002
Other occupational roles within the industry	Ref.			
Cough				
Yes	10.267	4.462	23.623	0.001
No	Ref.			
Time of Exposure (Duration of employment at Rutongo Mines)				
Short-Term Exposure: Less than 5 years	Ref.			
Medium-Term Exposure: 5–14 years	2.190	1.098	5.448	0.001
Long-Term Exposure: 15 years and above	5.714	3.599	19.773	0.001
Previous Positive COVID-19 Test				
Yes	3.867	1.661	4.256	0.018
No	Ref.			
HIV Status				
Positive	9.276	2.949	20.607	0.004
Negative	Ref.			
Tobacco smoking				
Yes	2.748	1.023	7.386	0.045
No	Ref.			
Previous TB treatment				
Yes	4.867	1.661	14.256	0.018
No	Ref.			
Other symptoms (chest pain, chronic cough, shortness of breath; bloody sputum)				
Yes	8.157	3.153	21.103	0.000
No	Ref.			
Working in Dust-Containing Crystalline Silica				
Yes	4.632	1.375	15.601	0.013
No	Ref.			
Working shift time: More than 8 hours				
Yes	3.241	1.545	6.947	0.012
No	Ref.			

Source: Primary data, 2025

The multivariate logistic regression analysis identified several factors significantly associated with silicosis among mine workers at Rutongo Mines Industry. Age was found to be a significant predictor; workers aged 50 years and above were 4.5 times more likely to develop silicosis compared to younger workers aged 18–34 years

(AOR=4.500, 95% CI: 1.424–14.216, *p*=0.010), while those aged 35–49 years did not show a statistically significant association (AOR=1.631, *p*=0.271).
Regarding education level, workers with no formal education or only primary education were about 2.1 times more likely to develop silicosis than those with secondary or tertiary education (AOR=2.107, 95% CI: 0.900–4.936, *p*=0.009). The analysis also showed a strong and statistically significant association between occupation and the occurrence of silicosis. Underground miners were found to be four times more likely to develop silicosis compared to those in other occupational roles (AOR = 4.021; 95% CI: 1.841–8.524; *p* = 0.002).
The presence of persistent cough showed a very strong association with silicosis, with affected individuals being 10.3 times more likely to be diagnosed (AOR=10.267, 95% CI: 4.462–23.623, *p*=0.001). Similarly, time of exposure was critical: workers employed for 5–14 years had 2.19 times higher odds of silicosis (AOR=2.190, *p*=0.001), while those with 15 years or more of exposure had a dramatically increased risk—5.7 times (AOR=5.714, 95% CI: 3.599–19.773, *p*=0.001).
Having tested positive for COVID-19 also showed a statistically significant association (AOR=3.867, 95% CI: 1.661–4.256, *p*=0.018). Additionally, workers who were HIV positive were 9.3 times more likely to develop silicosis compared to HIV-negative individuals (AOR=9.276, 95% CI: 2.949–20.607, *p*=0.004).
Tobacco smoking emerged as a significant risk factor as well, with smokers being nearly 2.75 times more likely to have silicosis (AOR=2.748, *p*=0.045). Those with a history of tuberculosis (TB) treatment were 4.87 times more likely to have silicosis (AOR=4.867, 95% CI: 1.661–14.256, *p*=0.018). The presence of other symptoms such as chest pain, shortness of breath, or blood-stained sputum showed a very strong association with silicosis (AOR=8.157, 95% CI: 3.153–21.103, *p*=0.000). Moreover, working in areas containing crystalline silica dust was associated with 4.63 times higher odds of silicosis (AOR=4.632, *p*=0.013). Finally, workers with shifts longer than 8 hours were more than 3 times more likely to develop silicosis than those working shorter shifts (AOR=3.241, 95% CI: 1.545–6.947, *p*=0.012).
and insufficient risk mitigation strategies.

Objective Two: To assess the factors associated with silicosis among mine workers of Rutongo Mines Industry

The multivariate analysis revealed that older age (50 years and above) was significantly associated with silicosis, with these workers being 4.5 times more likely to develop the condition compared to those aged 18–34 years (AOR=4.500, p=0.010). Although the 35–49 age group also had increased odds (AOR=1.631), the association was not statistically significant. This trend highlights the cumulative nature of silica exposure over time and the importance of early interventions.

The analysis also showed a strong and statistically significant association between occupation and the occurrence of silicosis. Underground miners were found to be four times more likely to develop silicosis compared to those in other occupational roles (AOR = 4.021; 95% CI: 1.841–8.524; *p* = 0.002). This finding highlights the critical need for targeted occupational health interventions and stricter dust exposure control measures in underground mining settings to reduce the burden of silicosis among high-risk workers.
Several personal health factors were also strongly associated with silicosis. Workers who had previously tested positive for COVID-19 were nearly 4 times more likely to have silicosis (AOR=3.867, p=0.018), while HIV-positive individuals had over 9 times greater odds (AOR=9.276, p=0.004) compared to HIV-negative counterparts. Additionally, tobacco smoking and previous tuberculosis treatment were statistically significant risk factors, increasing the odds of silicosis by 2.75 and 4.87 times, respectively. These findings underline the intersection of communicable diseases and occupational exposure in compounding respiratory risks.

On procedural factors, working in dust-containing environments, exposure for over 15 years, and working shifts longer than 8 hours were all significantly associated with higher silicosis risk. For example, workers with long-term exposure (15+ years) were nearly 6 times more likely to develop silicosis (AOR=5.714, p=0.001) compared to those employed for less than 5 years. Despite universal PPE reporting, the high exposure rates and shift durations suggest gaps in effective protection or adherence to safety protocols.

Conclusion

The study concludes that silicosis remains a public health concern among mine workers in Rutongo Mines Industry, with a prevalence of 10.1%. The condition is significantly associated with factors such as advanced age, underground mining, long-term exposure, tobacco use, HIV infection, COVID-19 history, and tuberculosis. While PPE usage was reported as universal, procedural risks persist, pointing to gaps in exposure control and worker protection. These findings call for stronger preventive measures, routine screening, and improved occupational health interventions tailored to high-risk groups.

Recommendations

Based on the findings of this study, the following recommendations are proposed for Rutongo miner industry:

1. Implement Regular Health Screenings: Conduct routine respiratory health check-ups, including chest radiography and lung function tests, especially for long-serving and older workers.
2. Enhance Dust Control Measures: Invest in improved dust suppression technologies and enforce stricter workplace ventilation standards to reduce exposure to crystalline silica.
3. Strengthen PPE Enforcement: Though PPE use was reported, there is a need to audit, monitor, and enforce proper usage and quality of respiratory protective equipment.
4. Target High-Risk Individuals: Provide specialized health education, monitoring, and support to workers with HIV, TB history, or smoking habits to mitigate compounded risks.
5. Limit Prolonged Shift Hours: Regulate working hours to not exceed 8 hours per shift and ensure breaks are enforced, especially in high-exposure zones.

Suggestion for further studies

Future research should explore the effectiveness of current preventive measures, such as PPE usage, dust control technologies, and workplace health education programs in reducing silicosis incidence. Additionally, longitudinal cohort studies could provide deeper insights into the progression of silicosis and the interaction of occupational exposures with comorbid conditions such as HIV and TB.

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