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Original Research

High blood pressure and exposure to dust from gold mine dumps among the elderly in South Africa: A cross-sectional study

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ABSTRACT

Objective: To investigate whether high blood pressure was associated with living close to a mine dump among the elderly in South Africa.
Study design: This was a cross-sectional study conducted among the elderly in communities 1–2 km (exposed) and 5 km or more (unexposed), from five pre-selected mine dumps in Gauteng and North West provinces of South Africa.
Methods: Structured interviews were conducted with 2397 elderly, using a previously validated ATS-DLD-78 questionnaire from the British Medical Research Council.
Results: The prevalence of high blood pressure was 57.51% in the exposed and 46.66% in the unexposed communities, respectively. Results from the multiple logistic regression analysis showed that having high blood pressure was significantly associated with living in exposed communities (AOR = 3.04, 95% CI: 2.41–3.83, P < 0.001). Other significant risk factors were being an previous and current tobacco smoker, age group, tertiary level of educational attainment, and having a history of occupational exposure to dust and chemical fumes.
Conclusion: The findings of this study suggest that there are high levels of blood pressure among the elderly residing in communities located near mine dumps in South Africa.

1. Introduction

Worldwide high blood pressure is a major public health concern and accounts for over 7.5 million deaths [1]. The increased prevalence of high blood pressure in developing countries is a growing concern because it is a major risk factor for cardiovascular diseases and an economic burden [2]. Epidemiological studies have indicated a significant positive association between air pollution exposure and increased cardiovascular diseases [3]. Numerous pollutants in the air including ozone, nitrogen dioxide, sulphur dioxide, carbon monoxide and particulate matter may deleteriously effects the vascular system [3]. Several studies have reported that environmental air pollutants such as gases and particulate matter are associated with increased mortality and morbidity from cardiovascular diseases [4–7] (see Fig. 1).

Various physiopathological pathway mechanisms of pollutants on the vascular system include oxidative stress and inflammation, direct effect on endothelial cells causing dysfunction or altering the autonomic nervous system [3]. These mechanisms may lead to blood pressure elevation and cardiac arrest. Even so further studies are required for full details on the mechanisms.

People who reside in proximity to mine dumps are exposed to polluted air that and contains a complex mixture of heavy metals and trace elements such as gold, copper, lead, zinc, arsenic, cadmium and selenium [8–12]. The elderly population are more vulnerable to the effects of air pollution because of ageing [8,13]. Mine dump facilities are major generators of wind-blown dust and one of the main sources of air pollution with potential adverse health implications for nearby communities [14,15]. The perennial dust problem is brought to the surrounding residents as a result of dying vegetation and reworking of old mine dumps to the for residual gold content [16,17] Fine dust particles are dispersed into the atmosphere and are carried away large distances. Research studies have shown that mine dumps are the perpetual

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contributors to the ambient particulate matter loading of the surrounding atmosphere.

Recently, there is increasing evidence that air pollution exposure is associated with high blood pressure. Results of an epidemiological study conducted found a significant positive association of blood pressure with air pollutants [18]. Another study conducted in China reported that populations with long term exposure to ambient air pollution experience higher blood pressures [19]. An experimental study found that exposure to combustion from organic components of fossil fuel was strongly associated with increased blood pressure and was a risk factor for heart attack [20].

Traffic has also been deemed as a source of air pollution, and studies have suggested that it increases arterial blood pressure [21]. Other studies conducted also showed a positive association between air pollution exposure and blood pressure [22–27]. However, there have been contrary studies which proved no associations between exposure to air pollution and increased blood pressure [28,29].

To the best of our knowledge, no study has investigated whether exposure to mine dust is associated with high blood pressure. Since very little is known about the effects of air pollution exposure on high blood pressure in the elderly population, we investigated the association between high blood pressure to exposure to dust from gold mine dumps in the elderly.

2. Methods

2.1. Data source, study design, and sampling

This study form part of a larger project by the Mine Health Safety Council of South Africa (MHSC) with the study methods documented elsewhere; however, we have provided a summary [8,9]. Data for this paper were from the cross-sectional study involving 2397 elderly people aged 55, and above living in exposed (1–2 km away from mine dumps) and unexposed (5 km + away from mine dumps) in Gauteng and North West province, South Africa was conducted in November and December 2012. The communities close to mine dumps (1–2 km away from mine dumps) were classified as exposed because they were located within the buffer zone [8,9]. The pre-selected mine dump facilities, communities and the targeted sample size for each community have been previously published. Communities situated around these mine dumps were selected because they had a large population density and are similar in terms of socio-demographic profile. These communities are located downwind from mine dumps and have high levels of dust fallout incidents [8,9]. A "knock on the door" approach was used to target people 55 years old and above who had been living in the communities for five years and more. Face to face interviews were conducted using a previously validated ATS-DLD-78 questionnaire from the British Medical Research Council. The study employed twenty-two highly trained field workers with two allocated to each community. The interviews were conducted in English and translated to a local language in the case where the participant did not understand. Sections in the questionnaire included demography, medical history, type of fuel used for cooking, heating and lighting, tobacco smoking habits, history of exposure to occupational hazards e.g. chemical fumes and dust. Quality control was ensured by randomly selecting 10% of the homes and re-administering the same questionnaire on interviewed participants and verifying their responses. A deviation of greater than 10% was deemed unacceptable.

2.2. Study measure

Having high blood pressure was classified based on a positive response to the following question: "Was the high blood pressure confirmed by the doctor?"

2.3. Statistical analysis

Collected data were entered to Epi Info version 3.5.3 and analyzed through STATA 15. Prevalence of the health outcome was calculated by dividing the number of study participants who responded affirmatively by the number of the completed questionnaires. A chi-square test was applied to determine the relationship between community (exposed/unexposed) and confounding variables. Crude and adjusted odds ratios (ORs) and 95% confidence intervals (CI) were calculated using univariate and multiple logistic regression analysis (LRA) to estimate the likelihood of having high blood pressure. Missing values were automatically excluded in each LRA model; therefore, each multiple LRA model had a different sample size. To obtain adjusted ORs for the effect of "community (exposed/unexposed)" on the outcomes were placed in an initial LRA model. This was followed by the addition of a potential confounder in a stepwise manner starting with the most statistical significant from the univariate analysis. Each time a new potential confounder was added to the model if the effect estimate between the

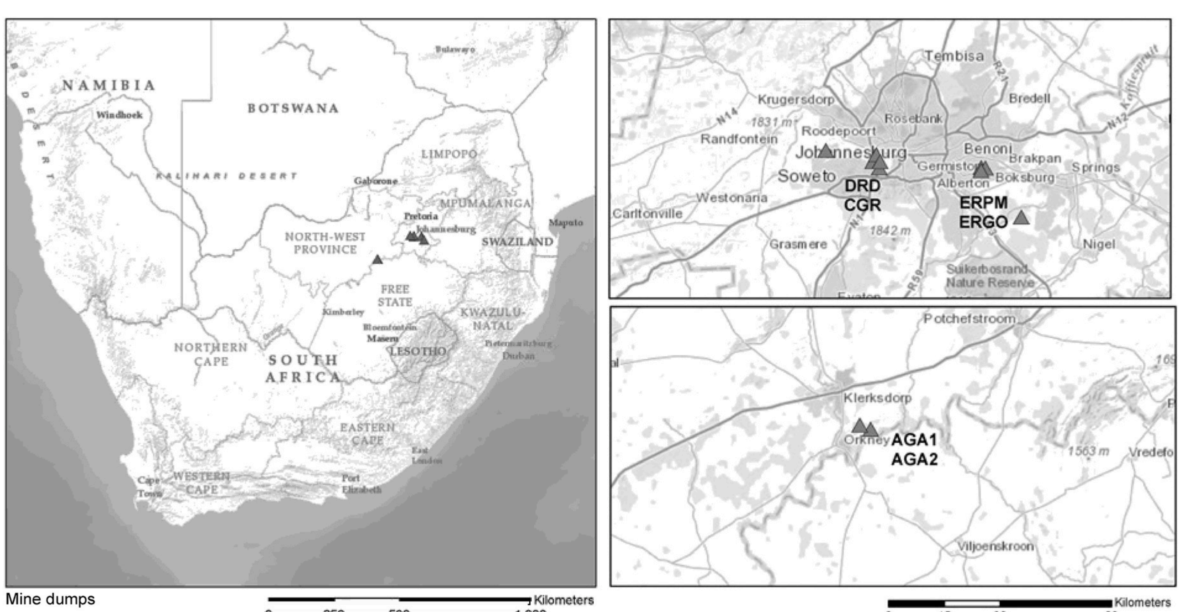

Fig. 1. Mine dumps included in the study.

exposure of interest and the high blood pressure outcome already in the models changed by more than 5%, the additional variable was retained in the final multiple LRA otherwise the variable was removed and a different one was added. The most parsimonious multiple LRA models were reported, i.e. those with variables having a p-value < 0.05. Effect modification between community (exposed/unexposed) and other air pollution source variables such as smoking habits, occupational exposure history to dust/chemical fumes and residential cooking/heating fuel type was investigated by including a multiplicative term in the model.

3. Results

The demographic characteristics of the study participants and air pollution variables have been published previously (Table 1) [25,26]. There were two thousand three hundred ninety-seven study participants, 1499 were from exposed communities, and 898 were from non-exposed communities.

The overall prevalence of high blood pressure in this study was 54.44%. In the unexposed, it was found to be 46.66% and 57.51% exposed communities. (Table 2). Results of the univariate analysis are shown in Table 3. Results from multiple logistic regression analyses (MLRA) (Table 4) show that living in exposed communities (AOR = 3.04, 95% CI: 2.41–2.17), being an ex-smoker (AOR = 16.25, 95% CI: 10.81–24.41), being a smoker (AOR = 1.78, 95% CI: 1.34–1.35), tertiary level of education (AOR = 2.11, 95% CI: 1.08–4.10), age group of 60 to 64 years (AOR = 1.32, 95% CI: 1.02–1.73) and age group of 70 to 84 years (AOR = 1.59, 95% CI: 1.20–2.11), and having a history of occupational exposure to dust or chemical fumes (AOR = 1.97, 95% CI: 1.52–2.51) were risk factors significantly associated with high blood pressure. However, a protective association between being coloured was observed (AOR = 0.37, 95% CI: 0.29–0.47) and using open fires as the main heating or cooking fuel type (AOR = 0.18, 95% CI: 0.04–0.77) with high blood pressure. The model was adjusted for sex, age, population group, level of education, tobacco smoking, history of occupational exposure to dust/chemical fumes and fuel type used for cooking/heating. No significant effect modification between community type (exposed/unexposed) and other air pollution sources variables was observed (results not shown).

Table 1
Demographic characteristics and air pollution variables in exposed and unexposed communities, during November – December 2012.

	Community		p-value[c]
	Exposed[a] (n = 1499)	Unexposed[b] (n = 898)	
Sex			
Female	774 (51.6)	472 (52.6)	0.66
Male	725 (48.4)	426 (47.4)	
Age (years)			
55-59	500 (33.4)	225 (25.1)	<0.001
60-64	405 (27.0)	221 (24.6)	
65-69	228 (15.2)	125 (13.9)	
70-84	309 (20.6)	278 (31.0)	
≥85	48 (3.2)	29 (3.2)	
Information missing	9 (0.6)	20 (2.2)	
Population group			
Black	1006 (67.1)	695 (77.4)	<0.001
[d]Coloured	493 (32.9)	203 (22.6)	
Level of education			
No schooling	262 (17.5)	271 (30.2)	<0.001
Primary	479 (32.0)	287 (32.0)	
Secondary	691 (46.1)	332 (37.0)	
Tertiary	67 (4.4)	8 (0.8)	
Tobacco smoking			
Non-smoker	888 (59.2)	598 (66.6)	<0.001
Ex-smoker	234 (15.6)	187 (20.8)	
Current smoker	377 (25.2)	113 (12.6)	
History of occupational exposure to dust/chemical fumes			
Yes	637 (42.5)	149 (16.6)	<0.001
No	862 (57.5)	749 (83.4)	
Main heating/cooking fuel type			
Electricity	1422 (94.8)	783 (87.1)	<0.001
Gas	31 (2.1)	67 (7.5)	
Paraffin	25 (1.7)	6 (0.7)	
Open fires	1 (0.1)	13 (1.5)	
Missing	20 (1.3)	29 (3.2)	

Figures in parentheses are percentages.
[a] Exposed: communities located 1 km–2 km from mine dumps.
[b] Unexposed: communities located 5 km or more from mine dumps.
[c] p-values of the Chi-square test.
[d] In South Africa, the term *Coloured* originated during the apartheid era to describe a distinct mixed ancestry people. The term is still used in South Africa as an official race group for census data and scientific research.

Table 2
Prevalence of high blood pressure during November – December 2012 among study participants in exposed and unexposed communities.

	High blood pressure		
	No	Yes	Total
Community type			
Unexposed	479 (53.34)	419 (46.66)	898 (37.46)
Exposed	637 (42.49)	862 (57.51)	1499 (62.54)
Total	1116 (46.56)	1281 (53.44)	2397 (100)

Figures in parentheses are percentages.
[a]Exposed: communities located 1 km–2 km from mine dumps.[b]Unexposed: communities located 5 km or more from mine dumps.

Table 3
Unadjusted odds ratios of high blood pressure and risk factors in unexposed and exposed communities during November-December 2012.

Variable	Odds ratio	95% CI	P-value
Community			
Unexposed	1	1	1
Exposed	2.45	2.04–2.96	<0.001
Sex			
Female	1	1	1
Male	0.87	0.73–1.05	0.139
Age (years)			
55–59	1	1	1
60–64	1.27	0.99–1.61	0.051
65–69	1.21	0.91–1.60	0.187
70–84	1.16	0.92–1.48	0.213
≥85	1.18	0.68–2.04	0.553
Population group			
Black	1	1	1
Coloured	0.58	0.48–0.69	<0.001
Level of education			
No schooling	1	1	1
Primary	1.12	0.88–1.44	0.382
Secondary	0.72	0.56–0.91	0.007
Tertiary	1.84	1.01–3.39	0.048
Tobacco smoking			
Non-smoker	1	1	1
Ex-smoker	10.06	6.92–14.61	<0.001
Current smoker	2.24	1.75–2.85	<0.001
History of occupational exposure to dust/chemical fumes			
No	1	1	1
Yes	2.33	1.88–2.88	<0.001
Main heating/cooking fuel type			
Electricity	1	1	1
Gas	0.60	0.39–0.91	0.017
Paraffin	1.58	0.70–3.56	0.273
Open fires	0.23	0.07–0.73	0.013

1: Reference category.

4. Discussion

To the best of our knowledge, no study has investigated whether exposure to mine dust is associated with high blood pressure. Since very

Table 4
Adjusted odds ratios of high blood pressure and risk factors in unexposed and exposed communities during November-December 2012.

Variable	Odds ratio	95% CI	P-value
Community			
Unexposed	1	1	1
Exposed	**3.04**	**2.41–3.83**	**<0.001**
Sex			
Female	1	1	1
Male	1.21	0.98–1.50	0.081
Age (years)			
55–59	1	1	1
60–64	**1.32**	**1.02–1.73**	**0.048**
65–69	1.35	0.97–1.87	0.069
70–84	**1.59**	**1.20–2.11**	**0.001**
≥85	1.77	0.95–3.03	0.072
Population group			
Black	1	1	1
Coloured	**0.37**	**0.29–0.47**	**<0.001**
Level of education			
No schooling	1	1	1
Primary	1.26	0.94–1.69	0.127
Secondary	0.88	0.65–1.18	0.378
Tertiary	**2.11**	**1.08–4.10**	**0.028**
Smoking habits			
Non-smoker	1	1	1
Ex-smoker	**16.25**	**10.81–24.41**	**<0.001**
Current smoker	**1.78**	**1.34–2.35**	**<0.001**
History of occupational exposure to dust/chemical fumes			
No	1	1	1
Yes	**1.97**	**1.52–2.51**	**<0.001**
Main heating/cooking fuel type			
Electricity	1	1	1
Gas	0.69	0.42–1.12	0.137
Paraffin	1.45	0.59–3.56	0.421
Open fires	**0.18**	**0.04–0.77**	**0.021**

1: Reference category.
Model adjusted for sex, age, population group, level of education, tobacco smoking, history of occupational exposure to dust/chemical fumes and fuel type used for cooking/heating.

little is known about the effects of air pollution exposure on high blood pressure in the elderly population, this study investigated the association between high blood pressure and exposure to dust from gold mine dumps amongst the elderly in North West and Gauteng Provinces in South Africa. The overall prevalence of high blood pressure in this study was 54.44%. According to the South African demographic household Survey report on people aged 60 years and older, more than half (53,6%) of the elderly population have high blood pressure [30]. In South Africa (SA), >30% of the adult population have hypertension [31], and it remains the single most common cardiovascular risk factor and the predominant contributor to cardiovascular disease and mortality [32].

An exposure assessment study conducted in mine dumps (this study) found ambient concentrations of particulate with an aerodynamic diameter less than 10 μm (PM10) which exceeded the 24-h limit set by the South African Department of Environmental Affairs (180 μg.m-3) [11]. Communities found downwind of mine dumps experienced higher dust concentrations than those located upwind. Residential developments in some communities are found at the foot of the mine dumps, causing elevated exposure to particulate matter. Dust deposits have a negative effect on visibility when it forms dust plumes, while deposition on fabrics, buildings, skin, eyes, and water tanks constitute a nuisance. The results of this study also indicated that the prevalence of high blood pressure was high in the exposed compared to the unexposed communities, and the elderly people that resided close mine dumps were at an increased risk of having high blood pressure. A possible maybe that once particulate matter are deposited in the lungs, pollutants may trigger an inflammatory response and induce oxidative stress through the generation of reactive oxygen species (ROS), the ultrafine particles can penetrate through the alveoli and cause injury to the cardiovascular system The ROS and pro-inflammatory cytokines released in the bloodstream to affect automatic cardiac control (heart rate, heart rate variability and cardiac contractility). The potential toxicity of mine dump dust particles may involve ROS formation, oxidative damage and inflammation and cause harm to the cardiovascular system [33–35].

Smoking cigarettes and high blood pressure have been reported to be highly prevalent in developed countries and even in developing ones. The results of this study are in line with those of a study conducted among residents aged 90 years or more in DuJiangYan district China in 2005. Individuals who were heavy smokers had higher diastolic blood pressure, compared with medium and light smoker [36]. Studies have indicated that when hypertension and smoking coexist in the same individual, the final cardiovascular risk rises dramatically. In addition, several relationships exist between some tobacco smoke compounds and blood pressure. Although cigarette smoking may not be associated with the development of essential hypertension, it has a significant impact on prognosis for hypertension, on the appropriate choice of therapy, and on the development of several unusual but significant consequences and secondary forms of hypertension [37].

Being a coloured and using open fire for cooking and heating the was protective against blood pressure. The results of this study showed that a history of occupational exposure to dust/chemical fumes is associated with high blood pressure. This is in line with the results of the studies conducted in Poland and China [38,39]. Those with higher educational attainment in this study were at an increased risk of having high blood pressure. The findings of this study are in contrary to those obtained study conducted in the United States of America [40]. A possible explanation may be dietary intake, those with a higher level of educational attainment have more income and exposed to unhealthy diet such as fast foods that predisposes them to the higher risk of having high blood pressure.

The limitations of this study have been previously published elsewhere [8,9]. First, the study cannot provide any evidence of causality. Second, no quantitative air pollution exposure assessment was conducted. Third, the interviewer error might have occurred in the translation of questions to the local language during the interview of some study participants who did not understand English. Fourth, the unwillingness of the respondents to provide honest answers or giving socially desirable responses should be taken into account in the interpretation of the results. Lastly, the differential participation rate between the exposed and unexposed communities is of concern, and it may well have introduced response bias, which is likely to overestimate the prevalence estimates derived from our cross-sectional study and also bias the association in either direction.

5. Conclusion

The findings of this study suggest that there are high levels of blood pressure among the elderly residing in communities located near mine dumps in South Africa.

Author contributions

VN and KV participated in the design of the study, data collection, statistical analysis and interpretation of the results, drafted and critically revised the manuscript; JS and FRT participated in the statistical analysis and the interpretation of the results, drafted and critically revised the manuscript. All authors have read and approved the final manuscript.

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Ethical approval

Ethical approval (Number: 235/2011) was obtained from the Research Ethics Committee of the Faculty of Health Sciences, University of Pretoria. A verbal and written consent was obtained prior to the commencement of the interviews.

Declaration of competing interest

None.

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