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Occupational health hazards of stone quarry workers of Nagaland, India

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Abstract

Background Occupational health is a neglected public health issue among stone quarry workers in developing countries. The quarrying sector poses large risks to their health and safety.

Objectives The objectives of this study are to investigate the impact of stone dust on cardiovascular and pulmonary health of stone quarry workers among an indigenous population of north-east India.

Sample and Methods This study was conducted in the Wokha district of Nagaland, North-East India. A total number of 152 Lotha male stone quarry workers aged 18–60 years and 152 adult males matched for ethnicity and age acting as the controls were selected for the present study. Blood pressures (both systolic and diastolic), oxygen saturation (SaO_2), pulse rate and forced vital capacity (FVC) were measured on each participant. Body mass index (BMI) was calculated following the standard equation. Multivariate multiple regression (MMR) analysis was used to examine the effect of stone dust on the cardiovascular and pulmonary health of the workers.

Results Preliminary statistics showed significant differences between the exposed and control groups in body weight, BMI, blood pressure, SaO^2, FVC and pulse rate ($p<0.05$). MMR results suggested that quarry workers revealed significantly ($p<0.0001$) lower systolic blood pressure (SBP), SaO^2 and FVC and a higher pulse rate ($p<0.0001$) than the control group.

Conclusions The study concluded that the exposure to stone dust among the quarry workers leads to deterioration of their cardiovascular and pulmonary health.

Take home message for students Inhalation of stone dust on a regular basis can damage cardiovascular and pulmonary health of an individual in the long run.

Introduction

Every occupation is basically associated with certain risks because of which a person may get certain diseases and/or injuries. This may happen suddenly or it may take years. The term "occupational hazards" is used to describe these health damages or injuries at the work place. Occupational hazard refers to risk or danger as a consequence of the nature or working condition of a particular job (Danna and Griffin 1999). For example, health and safety in the construction sector are very important issues due to the high accident rate at the construction sites, during building maintenance (Cortés-Pérez et al. 2020). Similarly, several studies have documented occupational risk factors faced by interventional cardiologists (Smilowitz et al. 2013), sanitation workers (Oza et al. 2022), meat processing industry workers (van Holland et al. 2015) and migrant workers in Europe (Diego-Cordero et al. 2021).

Stone quarry workers are no exception to the occupation hazards faced by other workers. Particularly in low-middle-income countries they are exposed to various forms of hazards, which have negative consequences on their wellbeing and performance at work, whereas in high-income countries various interventions and screening programs targeting stone quarry workers help improve their occupational health (Carvalho Sousa et al. 2020). The quarry industry is a challenging workplace because it poses severe risks to the occupational health and safety of these workers. The most important occupational risks related to stone quarrying include fatal accidents, physical injuries, and work related illnesses, e.g. respiratory diseases such as silicosis and tuberculosis due to inhalation of dust (Tribhuwan and Patil 2009). Needless to mention here, there are adverse health implications for people who work in silica dust polluted environments, suggesting the need for a national safety and health policy targeting them (Ahadzi et al. 2020). Active transmission of tuberculosis seems to be occurring among stone quarry workers (Carvalho Sousa et al. 2020). Other researchers also reported various work-associated illnesses due to occupational exposure to dust such as general body ache (Pathak R. K. and Dkhar J. W. 2010), chronic obstructive pulmonary disease (Blanc et al. 2009), hearing impairment as a result of exposure to excessive noise (Gyamfi et al. 2016), eye injuries (Ezisi 2019), and musculoskeletal disorders (Njaka et al. 2021). Exposure to heavy dust concentration from stone crushers can also produce diseases like pneumoconiosis (Zenz C. et al. 1994). Silicosis, caused by inhalation of dust containing silica, is another example of work-related respiratory diseases. Respiratory damage resulting from such exposure can cause emphysema, acute and chronic silicosis, and in extreme cases lung cancer (Mathur M.l. and Choudhary 1996).

Furthermore, poor working environmental conditions around crusher unit are the reason behind the poor state of health of the workers engaged in these stone crushing units (Gangopadhyay P.K. et al. 2004). The socio-economic conditions of the stone quarry workers are miserable and precarious as well. They live and work in a risky and unhygienic environment (Seddiky 2014). Quarry workers are more likely to be killed in accidents at any time than any other workers. A survey on occupational safety, hazards and related health problems among the quarry workers of India suggests that none of them is using any personal protective equipment. Furthermore, first aid boxes and ambulance facilities are not available at the site or nearby areas (Jobin et al. 2017). Quarrying activities can not only cause significant impact on health, but also on the environment. For example, frequent blasting of rocks with explosives in order to extract material for processing gives rise to noise pollution, air pollution, vibration and damage to biodiversity, and habitat destruction (Okafor 1988).

Short term exposure to particulate matter (PM) from air pollution contributes to acute cardiovascular morbidity and mortality; long-term exposure to elevated PM level can reduce life expectancy by several months to a few years (Brook et al. 2004). Similarly, other studies found detrimental effects of elevated concentrations of particulates in the inhaled air on the cardiovascular system of the quarry workers with an increase in systolic (SBP) and diastolic blood pressure (DBP) (Ibald-Mulli et al. 2001; Delfino et al. 2005; Pope et al. 2004; Linn et al. 1999) as well as heart rate (Pope and Dockery 2006). Uroko and Grace (Uroko and Grace 2020) observed that quarry workers showed elevated systolic, diastolic and mean arterial pressure, and a higher pulse rate than non-quarry workers.

The lungs are one of the most important organs exposed to environmental agents. Despite advances in technology, workers in stone processing industry continue to be at high risk for pulmonary function deterioration (Sheikh et al. 2018). Stone mine workers are prone to pulmonary problems due to stone dust, which is a great concern from a public health point of view. Many studies have delineated that cardio-respiratory functions in quarry workers are affected by stone dust exposure for example higher pulse rate and blood pressure, along with decreased pulmonary functions (Swami and Malik 1990; Swami et al. 1994; Subhashini and Satchidhanandam 2002; Kumar et al. 2014; Shaik et al. 2015), which is positively correlated with the duration of exposure (Subhashini and Satchidhanandam 2002; Singh et al. 2007; Rathod and Sorte 2013; Swami et al. 1994; Kumar et al. 2014). Particularly, peak expiratory flow (PEF) is significantly reduced in silica-exposed workers having respiratory morbidity (Tiwari et al. 2005). The duration of silica dust exposure is the most important determinant of pulmonary function deterioration: as the duration of exposure increases the pulmonary function decreases (Sheikh et al. 2018) with a significant reduction of forced vital capacity (FVC) and forced expiratory volume (FEV) (Gholami et al. 2020). The greatest reduction is evident with work duration of over 15 years (Subhashini and Satchidhanandam 2002).

Longsa village is one of the many villages in Wokha, a district of Nagaland in North-East India largely populated by the indigenous Lotha population. Literal translation of the name Longsa is embedded/covered by stones. The village is actually surrounded by several quarries. As a consequence, the population living in this village, of which the majority are Lotha, are constantly exposed to the stone dust. The majority earn their livelihood by working in these stone quarries. Consequently, such exposure makes them susceptible to developing various respiratory diseases and pulmonary function related problems. Thus, based on our literature survey, we hypothesize that pulmonary function of the Lotha stone quarry workers will be significantly reduced as compared to their non-quarry worker counterparts. Keeping this overarching hypothesis in mind, the present study aims to test this hypothesis by examining the cardiovascular and pulmonary functions of the Lotha stone quarry workers as compared to the Lotha non-quarry workers with special emphasis on investigating whether stone quarrying as an occupation can be a causative factor for the deterioration of the cardiovascular and pulmonary function of Lotha stone quarry workers of Longsa village of Wokha district, Nagaland.

Samples and Methods

Samples

The Lotha Naga constitute one of the major tribes of the state of Nagaland, North-East India. Wokha is the traditional home of the Lotha tribe. The Wokha district is situated in the mid-western part of Nagaland. It is generally known for its rich mineral resources, soil fertility and abounding flora and fauna. The present study was carried out at stone quarries situated in Longsa village of Wokha district of North-East India. A cross-sectional sample of N=304 (152 exposed and 152 control) adult males aged 18–60 years was collected. Stone quarry workers in Longsa village engaged in any type of quarrying activities served as participants (152 adult males). Purposive sampling was employed for the selection of subjects. Careful selection was carried out to specifically include only the Lothas, even if other tribes were working in the quarry sites during the data collection. Another 152 adult males, with age and ethnicity matching those of the exposed group but not exposed to stone dust participated as the control group. The control group was sampled from two villages, namely Longsachung (5.2 km away from Longsa village) and Yikhum (20 km away from Longsa village) which fulfilled the following criteria: no stone quarry in the village, no inhabitant of the village working in the stone quarries, and Lotha dominated population. Written informed consent was obtained from all the participants for this study. Institutional ethical clearance was obtained from the North-Eastern Hill University, Shillong, India.

Methods

Anthropometric measurements such as height and body weight were taken of each participant following standard protocols (Tanner et al. 1969). Body mass index (BMI) was calculated using the formula body weight (kg)/stature (m^2). Standard BMI classification was used in the present study following WHO cut-off points for Asian population (WHO 2004). This was as follows: underweight = <18.5 kg/m^2, normal weight = 18.5-22.9 kg/m^2, overweight = 23.0-24.9 kg/m^2 and obese = 25.0 kg/m^2. Blood pressure, both SBP and DBP, was measured using a standard mercury sphygmomanometer (Diamond Mercurial Type Conventional BP Monitor-Deluxe) and stethoscope. Blood pressure categories were defined following the American Heart Association (Hunt 2005), as this is the most widely accepted classification in anthropological and public health related research. Blood pressure was classified as follows: low normal = <119/79 mmHg, normal = 120–130/80-84 mmHg, and hypertension = 131/85 mmHg. Forced vital capacity (FVC) was measured using a portable spirometer (Baseline 12–1710 Windmill-Type Buhl Spirometer). Arterial oxygen saturation at rest (SaO^2), which is a measure of the oxygen carrying capacity of hemoglobin in the blood, and pulse rate, which measures the frequency of pressure waves, i.e. waves per minute, propagated along the peripheral arteries, such as carotid or radial arteries, were measured using a pulse oximeter.

Statistical analyses

All the statistical analyses were computed using IBM-SPSS software (version 26.0). Descriptive statistics in the form of mean and standard deviation were computed. The t-test and chi-square test were used to evaluate the differences in anthropometric and physiological parameters and their categories between exposed and control groups. Pearson's correlation coefficient was calculated between anthropometric and physiological variables in both exposed and control groups separately to examine the relation between the above-mentioned variables with each other. Multivariate multiple regression (MMR) analysis was computed by considering SBP, DBP, BMI, SaO^2, pulse rate and FVC as dependent variables, and age and study groups (exposed vs. control) as independent variables. The reason behind using such regression model is that we wanted to capture the influence of predictive variables on the dependent variables simultaneously and not separately. For example, BP is the combination of both SBP and DBP.

Results

Descriptive statistical analyses of anthropometric and physiological characteristics showed significant differences in body weight ($p<0.05$), body mass index ($p<0.01$), blood pressure ($p<0.01$), oxygen saturation ($p<0.001$), FVC ($p<0.0001$) and pulse rate ($p<0.05$) (Table 1).

Mean body weight, BMI, blood pressure, FVC and oxygen saturation are significantly higher in the control group as compared to the exposed group while mean pulse rate is higher among the exposed group. Significant differences in both SBP ($p<0.001$) and DBP ($p<0.05$) were observed between the exposed and the control groups (Figure 1 & 2).

In SBP, considerably greater prevalence of low normal blood pressure ($34.0\%_{\text{Exposed}}$ vs. $8.1\%_{\text{Control}}$) was observed among the exposed group as compared to the control group, whereas the prevalence of hypertension in SBP ($44.6\%_{\text{Control}}$ vs. $20.0\%_{\text{Exposed}}$) was found to be higher among the control group than the exposed group (Figure 1).

Similarly, in DBP, prevalence of low normal blood pressure ($17.3\%_{\text{Exposed}}$ vs. $8.1\%_{\text{Control}}$) was found to be higher among the exposed group, while greater prevalence of hypertension ($52.7\%_{\text{Control}}$ vs. $43.3\%_{\text{Exposed}}$) was observed among the control group (Figure 2).

BMI categorization showed no significant differences between the exposed and the control group (Figure 3). However, prevalence of underweight ($14.6\%_{\text{Control}}$ vs.

Table 1 Descriptive statistics of anthropometric and physiological characteristics among the Lotha of Nagaland

Anthropometric and physiological measurements	Exposed group			Control group			t-Values	p-Values*
	N	Mean	SD	N	Mean	SD		
Age (years)	152	36.28	10.39	152	41.34	11.88	-3.95	**0.014**
Height (cm)	152	165.39	6.17	152	165.83	6.48	-0.60	0.716
Body weight (kg)	152	57.72	8.38	152	58.56	9.34	-0.82	**0.045**
Body Mass Index (kg/m^2)	152	21.06	2.46	152	21.26	2.91	-0.66	**0.009**
Systolic blood pressure (mmHg)	150	123.73	14.21	148	133.51	14.98	-5.78	**<0.0001**
Diastolic blood pressure (mmHg)	150	83.08	10.29	148	86.15	9.30	-2.70	**0.007**
Oxygen saturation (%)	152	94.26	6.89	152	95.84	4.78	-2.32	**0.021**
Pulse rate (per minute)	152	79.11	13.89	152	73.28	12.05	3.89	**0.045**
Forced Vital capacity (liter/minute)	150	2.346	0.58	148	2.639	0.65	-4.09	**<0.0001**

*significant p values are highlighted in bold

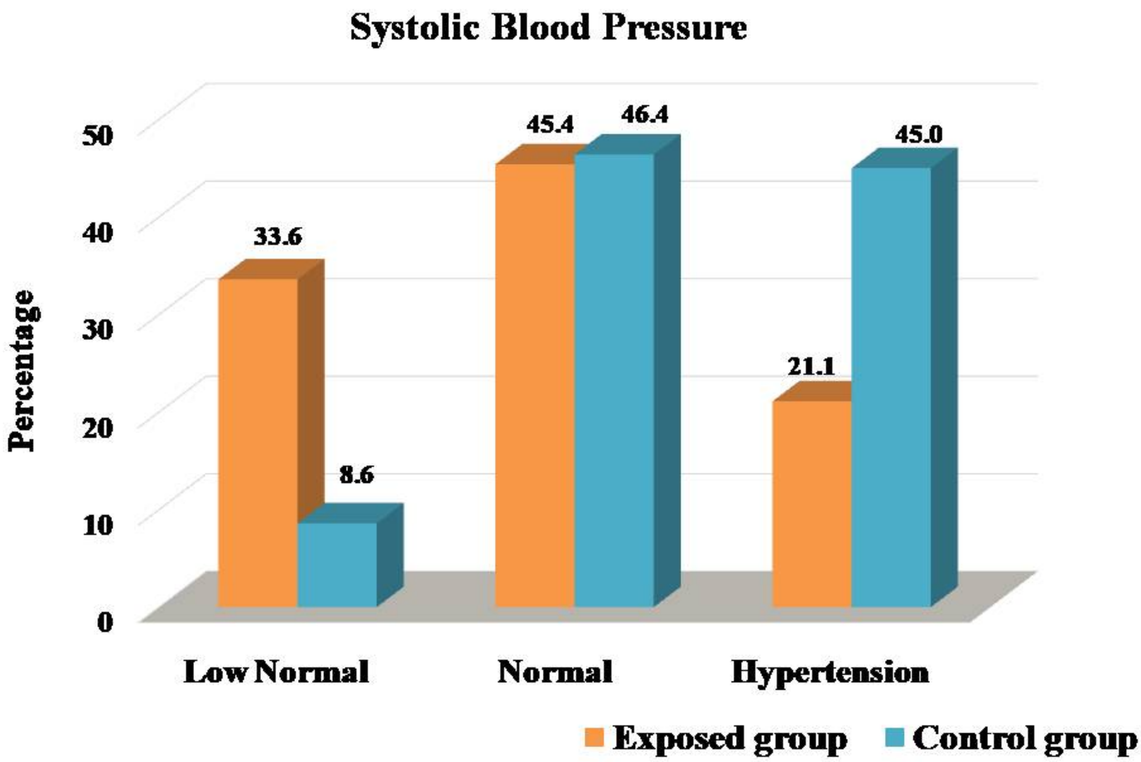

Figure 1 Systolic blood pressure among the Lotha, by study groups χ^2 test (exposed vs. control differences): 38.710 (p-value: 0.000; df: 2)

9.9%$_{Exposed}$) and overweight (11.9%$_{Control}$ vs. 7.9%$_{Exposed}$) was greater among the control group than the exposed group (Figure 3). No cases of obesity were observed among the two study groups of Lotha population. FVC was found to be significantly correlated with height, body weight and blood pressure among the control group (Table S2), but not among the exposed group (Table S1). Table 2 presents the results of MMR analysis of age and study groups on selected physiological variables among the Lotha of Nagaland. Both age and study group (exposed vs. control) were found to be crucial confounding factors which significantly influenced almost all the dependent variables. These two indicators alone explained ~11% of variation in SBP and FVC. Age significantly influenced the prevalence of hypertension in both SBP and DBP ($p<0.001$), and overweight in BMI ($p<0.05$). With advanced age Lotha Naga were prone to become hypertensive, for both SBP and DBP as well as overweight. With advanced age the Lotha had significantly reduced FVC ($p<0.001$). The study groups differed significantly ($p<0.001$) in the prevalence of systolic hypertension, but not diastolic hypertension (Table 2). The stone quarry workers, i.e. members of the exposed group, tended to have lower SBP than their counterpart control group. Lotha exposed to stone dust showed significantly ($p<0.05$) lower oxygen saturation and significantly lower FVC ($p<0.001$) than the control group. In addition, there was a significant ($p<0.001$) increase in pulse rate among the quarry workers as compared to the control group (Table 2).

Discussion

The present study is one of very few studies conducted in North-East India, focus-

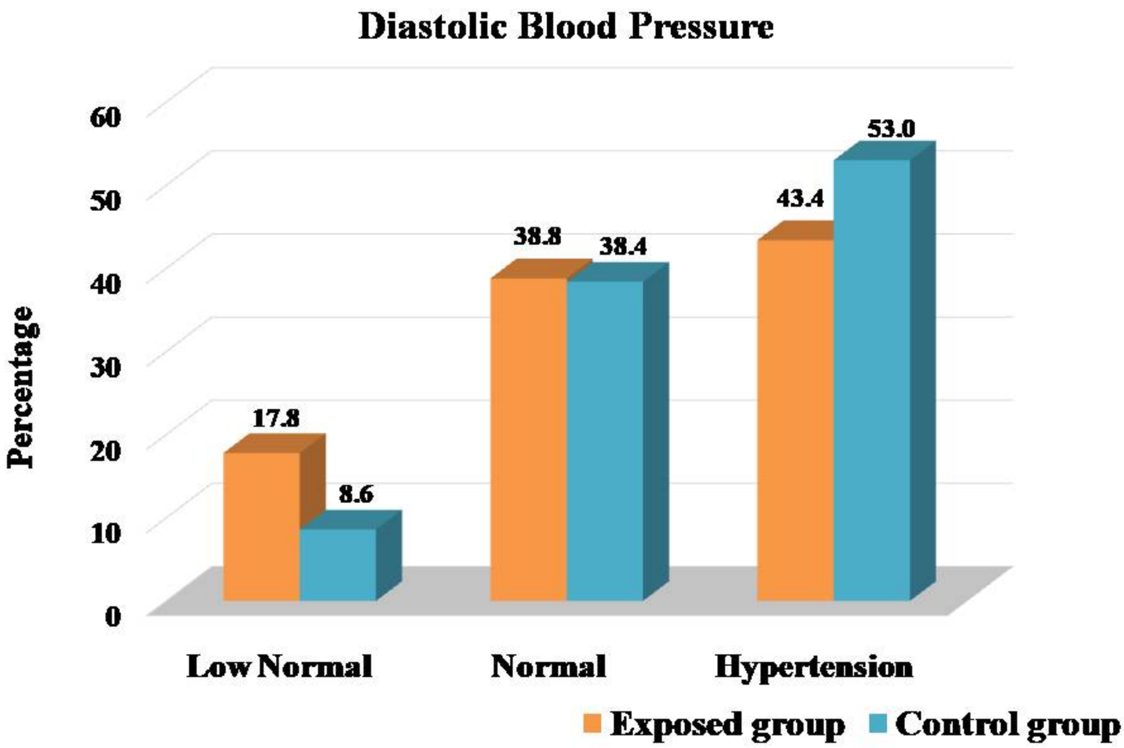

Figure 2 Diastolic blood pressure among the Lotha, by study group: χ^2 test (exposed vs. control differences) 6.335 (p-value: 0.042; df: 2)

ing on public health related issues of the stone quarry workers. The major objective of this study was to examine the cardiovascular and pulmonary functions of the stone quarry workers of Nagaland, North-East India, in order to test our formulated hypothesis that stone quarry workers will show more deteriorated vital measures as their non-quarry worker counterparts. In addition, the study investigated the effect of occupational hazards on the cardiovascular and pulmonary health of stone quarry workers as compared to the control group. Several quarries are situated in and around the dwelling places of the Lotha stone quarry workers. As a consequence, they are constantly exposed to the stone dust from these quarries, even outside the working hours. Some even live in tents. This makes them constantly exposed to stone dust throughout the year. The detrimental effect of such exposure is clearly evident in the pulmonary health of the Lotha stone quarry workers. Similar findings were also reported by previous researchers (Carvalho Sousa et al. 2020; Blanc et al. 2009; Brook et al. 2004; Subhashini and Satchidhanandam 2002; Shaik et al. 2015; Gholami et al. 2020; Sheikh et al. 2018; Gangopadhyay P.K. et al. 2004; Swami et al. 1994; Kumar et al. 2014).

In particular, being exposed to stone dust significantly affects SaO_2, pulse rate and FVC. Stone quarry workers showed significantly lower levels of SaO_2 as compared to the controls. As mentioned above, such a result could be due to their (exposed group) daily inhalation of stone dust, as a consequence of which their lungs are deprived of the required amount of oxygen. Similar findings of decreased SaO_2 were also reported by earlier researchers for the mine tailing community in Kolar, India (Shenoy and Kutty 2018), and among cobblestone workers in Addis Ababa, Ethiopia (Mamo 2018). The higher pulse rate among the

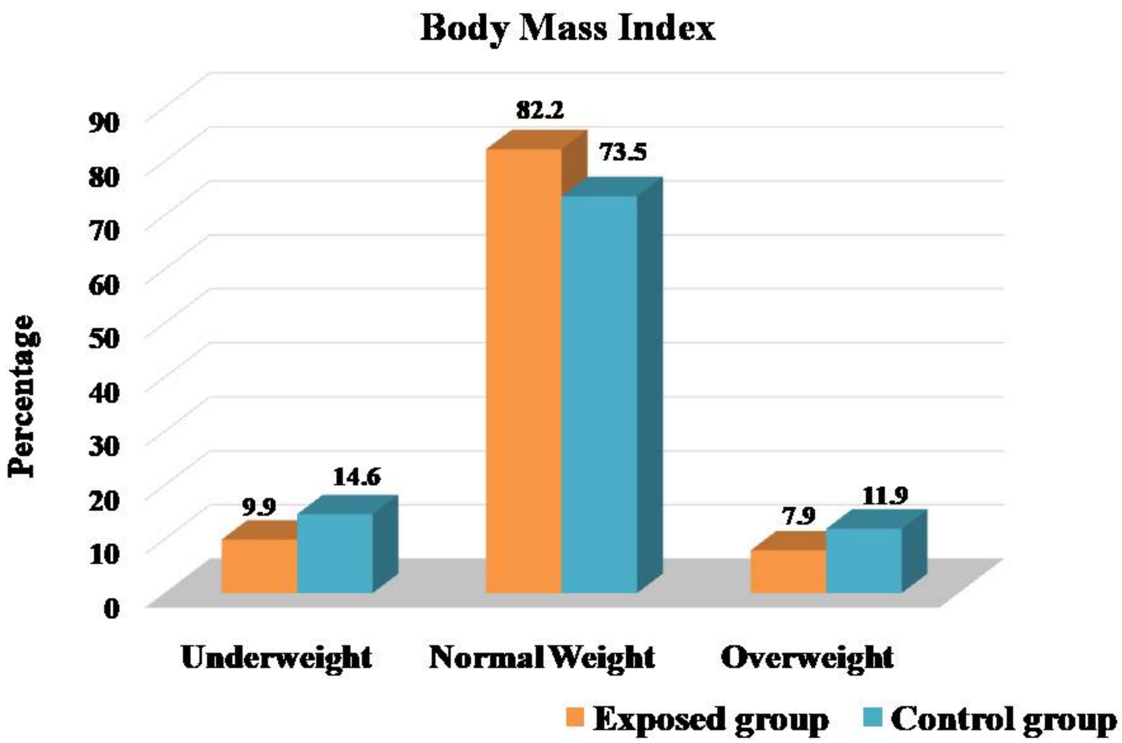

Figure 3 Body mass index among the Lotha, by study groups χ^2 test (exposed vs. control differences): 3.352 (p-value: 0.187; df:2)

exposed workers might compensate for the lower SaO_2 which was also reported by other researchers (Swami and Malik 1990; Shenoy and Kutty 2018; Uroko and Grace 2020). The low values of FVC among the exposed quarry workers is in line with previous studies (Subhashini and Satchidhanandam 2002; Shaik et al. 2015; Gupta et al. 1999; Kumar et al. 2014). The reason behind the reduced FVC could be due to their exposure to dust containing silica that leads to deterioration of pulmonary function, as was also suggested by earlier researchers (Kumar et al. 2014). The reduction in FVC could also be related to the exposure duration and exposure concentrations (Singh et al. 2007). Even low dust level exposure for long duration can result in pulmonary function impairment. This impairment of lung function increases with age and is associated with smoking status and the duration of dust exposure (Ghotkar et al. 1995).

Previous studies have documented various levels of awareness and utilization of protective measures among quarry workers of different countries. For example, for quarry workers from Ghana, recommendations for occupational safety and sensitization programs as well as medical check-ups and screening of workers were provided (Baah-Ennumh et al. 2021), whereas, a screening program targeting stone quarry workers was found to be implemented in Northern Portugal (Carvalho Sousa et al. 2020). In another study among the stone quarry workers of south-eastern Nigeria, it was found that although they were all aware about work-related health hazards and utilization of personal protective devices, most of them refused its use for various reasons (Ezisi et al. 2017). This suggests that the worker's perception of job-related health risk and willingness to use various protective measures are as important to consider as the awareness program itself.

The present findings indicate higher prevalence of low normal SBP among the exposed group than the control group. This finding is in contradiction with other studies, which reported elevated SBP among stone quarry workers (Mamo 2016; Panwar et al. 2016; Uroko and Grace 2020), due to the exposure to particulate matter (Ibald-Mulli et al. 2001; Brook and Rajagopalan 2009). In addition, findings from controlled

Table 2 Main results of multivariate multiple regression analysis of age and study groups on selected physiological variables among the Lotha of Nagaland

Dependent variables	Confounding variables	coefficient	SE	p-values
Systolic blood pressure (normal vs. hypertension)	Age	0.009	0.002	<0.0001
	Study groups			
	exposed	-0.193	0.053	<0.0001
	control ≠	–		
Multiple R^2		11.4%		
Diastolic blood pressure (normal vs. hypertension)	Age	0.024	0.006	<0.0001
	Study groups			
	exposed	-0.157 -	0.134	0.243
	control≠	–		
Multiple R^2		6.9%		
Nutritional status (normal vs. overweight)	Age	0.005	0.002	0.026
	Study groups			
	exposed	0.034	0.055	0.535
	control≠	–		
Multiple R^2		1.7%		
Oxygen saturation	Age	0.010	0.030	0.752
	Study groups			
	exposed	-1.349	0.699	0.051
	control	–		
Multiple R^2		1.5%		
Pulse rate	Age	-0.064	0.067	0.339
	Study groups			
	exposed	5.823526	1.531	<0.0001
	control≠	–		
Multiple R^2		5.7%		
Forced vital capacity	Age	-0.013	0.003	<0.0001
	Study groups			
	exposed	-0.359 -	0.071	<0.0001
	control≠	–		
Multiple R^2		10.6%		

≠ Reference category

human exposure experiments showed that short-term exposure to fine ambient particulate matter significantly increases SBP and non-significantly increases DBP (Bellavia et al. 2013). One of the reasons for higher prevalence of hypertension in SBP among the control group of this study could be age. The mean age of the control group was higher than that of the exposed group. Regression analysis of the study groups on selected physiological variables among the Lotha of Nagaland showed significant differences in all parameters except BMI. This may be because Lotha Naga, irrespective of the fact whether they were from the exposed or control groups, consume a similar diet consisting of protein-rich food, whole-grain foods, pulses, fruits and green leafy vegetables as observed during the fieldwork. Besides, they put in a lot of physical labor everyday, especially the stone quarry workers, which in turn might prevent them from developing obesity.

The study also revealed a significant effect of age on both systolic and diastolic hypertension ($p<0.001$) and overweight ($p<0.05$), irrespective of exposure to stone dust. Thus, age was found to be a crucial positive determinant of overweight and hypertension among the Lotha Naga, which was also observed by other researchers in neighboring populations, such as the Hmars (Lalnuneng and Khongsdier 2017) and Tangkhul Naga of Manipur (Mungreiphy et al. 2011), the tribal population of Mokokchung, Nagaland (Tushi et al. 2018). In addition, the study also found a statistically significant ($p<0.001$) effect of age on FVC. With increase in age, the Lotha were found to have decreased lung capacity, which was also documented in previous studies (Pruthi N. and Multani 2012; Malakar and Roy 2016; Thomas et al. 2019). Thus, it is evident from the present and previous studies that lung function declines with progression of age. Limitations of our study include the fact that we could not control for every lifestyle factor and age among the control group due to limited sample size and inaccessibility of some locations due to fear of Covid-19 when the study was conducted. Moreover, several other work-related health hazards of the stone quarry workers, like eye injuries, accidents, were not included in the present study.

Conclusion

Constant exposure to stone dust for the quarry workers was found to be a crucial confounding factor, which impacted blood pressure, oxygen saturation, pulse rate and FVC among these Lotha Naga. In particular, it was observed that, due to occupational health hazards, cardiovascular and pulmonary health of the Lotha stone quarry workers were significantly more deteriorated than in people from the same ethnic community not exposed to stone dust. This demonstrates cardiovascular stress and deterioration of lung function due to stone dust inhalation among the quarry workers. We suggest the use of face-mask or Air-Purifying Respirators (APRs) by stone quarry workers, as per the nature of work, to prevent inhalation of stone dust from quarrying activities. In addition, measures should be taken to control health hazards, such as creating awareness among the quarry workers of the consequences of stone dust exposure as well as taking preventive measures for the promotion of cardiovascular and pulmonary health.

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