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A Comparative Study on Changes in Cardiovascular Indices of Cobblestone Workers in Addis Ababa, Ethiopia

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Abstract

Cobblestone projets have become good job opportunities for hundred thousands of citizens. However, workers are at risk of health problems due to physical injury and exposure to dust particles during work activities. The study was designed to determine acute and chronic changes in cardiovascular indices of cobblestone workers in Addis Ababa, Ethiopia. Comparative cross-sectional study method was applied. Cobblestone workers exposed for one and above years and proportional number of non exposed groups from Addis Ababa University summer non- smoking normal students within the same age range and sex proportion were participated. Acute exposure standard was established on an eight-hour exposure time frame. HR, $\%SPO_2$ and ABP were measured before and after a day work exposure, using pulse oxi-meter and sphygmomanometer. The study showed significant change in cardiovascular indices compared with controls. The mean value of $\%SPO_2$ was reduced significantly ($p=0.03$) in exposed groups compared to non exposed groups. The mean value±SD of HR in exposed groups showed very significant increment ($p=0.001$) and variability was reduced. Both sPB ($p=0.006$) and dBP ($p=0.001$) showed very significant increment. From this study, it could be concluded that dust emission during cobblestone work affects the cardiovascular function of cobblestone workers. Acute and chronic exposure to dust for some hours leads to very significant changes in cardiovascular indices. Regular inspection and further study is recommended together with full co-operation among the competent authority, researchers, workers and occupational health professionals.

Keywords: Cardiovascular indices; Cobblestone workers; Comparative study.

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1. Introduction

Cobblestone projects; paving roads with small and shaped stones have become major alternative for Ethiopian road construction. It is labor intensive and does not require sophisticated skill providing job opportunities for hundred thousands of citizens. However, workers are at risk of physical injury and exposure to dust particles during excavating, cutting, drilling, handling, loading, transporting, chiseling and paving activities inducing acute and chronic cardio-pulmonary problems.

Stone materials and fine dust in the underground have metals and other substances that are dangerous for health [1, 2]. Most rocks and soil containing silica has associated with human diseases [3-5]. The workers exposed to stone dust suffer from lung diseases which are associated with cardiovascular complications [6-8].

Dust particles induce pulmonary and systemic inflammation, accelerating atherosclerosis and altering cardiac autonomic functions [8]. Some studies in selected human samples and animal models suggested that higher levels of ambient particles could be associated with effects on autonomic function including heart rate, blood pressure, coronary heart disease and heart rate variability [9-13]. Changes in cardiac parameters such as an increase in the S-T segment were observed in dogs and rats with coronary occlusion after exposure to particulate matter [13]. The extent of exposure depends on the types of agent mostly associated with nature of work and environmental characteristics [7].

Other studies indicated that dust has two different effects; acute that occurs almost immediately after breathing heavy dust and the other chronic effect confirmed only after several hours or days of inhaling dust [1,11,14-15]. Therefore, the present study was designed to assess the acute and chronic comparative changes in cardio-vascular indices of cobblestone workers in Addis Ababa, capital city of Ethiopia.

2. Materials and Methods

Comparative and cross-sectional study method was applied on cobblestone workers at eight sites in Addis Ababa. About 155 (82 chiseling and 73 quarry) workers within 18-35 years age range and exposed for one and above years were involved. Proportional number of non exposed individuals was participants from Addis Ababa university summer degree non- smoking normal students within the same age range and sex proportion. Among non-exposed participants (n=151), 128(84.1%) were males and 23(15.9%) were females checked to fulfill the inclusive criteria. Study protocol was approved by Addis Ababa university medical ethical committee then Written and verbal informed consent was obtained from study participants. The quarry workers were all males while the chiseling workers were both male (M=59) and female (F=21) workers. In the course of the study, promising extraneous factors like type of stone work, sex, age and duration of exposure were considered for comparison of changes. Systematic random sampling was applied based on work division differing in nature of activities and sex proportion. Acute exposure standard was established on an eight-hour exposure time frame. HR, %SPO2 and ABP were taken early morning and after eight hour work activities. Oxi-Max N-65 hand pulse oxi-meter (COVIDIEN-NILLCOR and PURITAN BENNET Colorado USA) was used to record heart rate and hemoglobin saturation of arterial blood with oxygen (%SPO_2).

Standard mercury column sphygmomanometer with the cuff size of 52 X14 cm was used together with a stethoscope to measure the arterial blood pressure (ABP).Those with abnormalities of cardio-respiratory diseases and complications were excluded. Cardio-vascular indices were compared between exposed and non exposed participants and the subgroups by independent sample t-test. Paired t- test was applied to compare pre and post shift cardio-vascular measurement.

3. Result

Demographic characteristics

The job and general description of non exposed group and exposed subjects is shown in table 1. The mean duration of stay for quarry workers was 3.95± 2.03 years while the chiseling workers were 3.03 ±1.02 years.

Table 1: Job and general description of non exposed group and exposed subjects

Non exposed group (n=151) (Controls)		Exposed (n=155) (Cobblestone workers)		Cobblestone workers stayed in the work (Mean±SD) in year
Number (%)		Number (%)		
Male	127 (84.1%)	Quarry workers	Male 73 (47.1%) Female 0 (0%)	(3.95± 2.03
Female	23 (15.9%)	Chiseling workers	Male 61(39.5%) Female 21(15.4%)	(3.03±1.02

Regarding educational level, about 49% of the non exposed groups were diploma holders while the remaining 51% were degree holders attending graduate study.

About 15.9% of the exposed group was illiterate. Majority of the cobblestone work participants had primary (52.4%) and secondary (27.6%) education while 4.1% of the workers attended tertiary education.

Saturation of Hemoglobin in Arterial Blood (%SPO_2)

Independent t-test was used to compare between non exposed group and exposed group as well as between the subgroups. There was significant difference (p=0.030) between non exposed group (mean±SD = 97.272 ±1.306) and exposed groups (mean±SD=96.942±1.330).

Heart Rate and Blood Pressure

Cardiovascular variables (heart rate and blood pressure) showed variation between exposed groups and their matched non exposed group. There was difference between SEGs compared each other (table 3).

Table 2: Mean±SD of $\%SPO_2$ measurement for both non exposed group and exposed group

Parameter	Non-exposed group (n=151)	Exposed (n= 155)	t-value	p-value	Quarry (n=73)	Chiseling (n=82)	Difference	t-value	p-value
$\%SPO_2$	97.27 ± 1.30	96.94 ± 1.33	-2.19	0.03	96.92 ±1.31	97.07 ±1.31	-0.15	-1.38	0.09

Table 3: Mean±SD of HR and BP measurement for both non exposed group and exposed group

Parameters	non-exposed group (n=151)	Exposed (n=155)	t-value	p-value	Quarry (n=73)	Chiseling (n=82)	t-value	p-value
Heart rate (bpm)	70.04± 6.707	73.226± 9.734	3.319	0.001	75.05± 10.793	69.949± 9.073	2.898	0.004
Systolic BP (mmHg)	110.35± 10.179	113.311± 8.463	2.759	0.006	112.46± 9.578	110.254± 9.932	1.297	0.197
Diastolic BP (mmHg)	72.806± 8.548	76.112± 8.114	3.468	0.001	74.589± 7.301	72.457± 7.733	1.624	0.107

Acute Change in $\%SPaO_2$ Heart Rate and Blood Pressure

Table 4: Paired t-test showing the difference of pre and post measured $\%SPO_2$, heart rate and ABP across groups

Parameter	Group	Mean± SD		Mean difference	t-value	p-value
		Before starting work	After working day			
$\%SPO_2$	Quarry	96.548±1.281	95.931±1.262	0.616	4.840	0.000**
	Chiseling	97.261±1.301	96.279±1.239	0.982	82.719	0.000**
Heart rate (bpm)	Quarry	74.739±10.536	75.657±10.410	-0.918	-1.836	0.070
	Chiseling	71.100±8.975	71.993±8.606	-0.893	-16.868	0.000**
SBP (mmHg)	Quarry	112.671±9.685	115.726±9.205	-3.055	-4.187	0.000**
	Chiseling	109.740±0.357	111.092±10.036	-1.352	-15.967	0.000**
DBP (mmHg)	Quarry	74.384±7.497	76.644±6.564	-2.260	-3.042	0.003*
	Chiseling	72.195±8.696	73.970±8.894	-1.774	-23.584	0.000**

4. Discussion

Exposure to ambient particles is an important risk factor for cardiovascular morbidity and mortality. Exposure is associated with increased blood pressure, reduced heart rate variability, increased heart rate, endothelial dysfunction and myocardial ischemia [9, 13- 15]. Breathing high concentrations of fine dust elicits changes in autonomic heart rhythms [9].

At the cobblestone working sites, workers have been exposed to various dusts and physical injuries. The present study has showed changes in cardiovascular indices. When ventilation increases, breathing shifts from nasal to a combination of oral and nasal breathing increasing air bypass cleansing naso-pharynx and further ever-increasing the exposure of the lower airways to inhaled dust particles [16]. Dust particles cause major health problems because they can pass through the lungs into other organs of the body [17-20]. Such mixing with air could reduce the partial pressure of oxygen within blood. Size and chemical nature of the dust particles determine extent of effect on the body.

There was significant difference ($p=0.030$) in $\%SPaO_2$ between non exposed group (mean±SD = 97.272±1.306) and exposed groups (mean±SD =96.942±1.330) with 5% standard error. Hemoglobin (Hb) is oxygen transporting protein in the blood which is composed of four polypeptide chains each containing one heme or iron ion [21]. The difference between the two subgroups was not significant ($p=0.089$) although the mean value for chiseling workers was higher. Under normal circumstances, the PO_2 in lungs capillaries is 100 mm Hg and Hb is almost completely saturated with oxygen. Since the PO_2 of blood cannot change until the blood reaches the capillaries in the tissues, all arterial blood is expected to be just about100% saturated. As it reaches to the tissues, the partial pressure of oxygen (PO_2) decreases leading to reduction in the percent saturation. When blood is leaving the tissues, 70% saturation is the typical $\%SPO_2$ in the capillaries of resting tissues [21].

Oxygen binding to hemoglobin is determined by the partial pressure of oxygen (SPO_2), PH and hemoglobin concentration. Oxygen tension, temperature and organic phosphate also affect it [22]. Hypoxemia could cause low oxygen saturation (SPO_2) on pulse oxi-metry secondary to pulmonary disease [23]. The pulmonary diseases result in hypoventilation, mismatching of ventilation and perfusion, right-to-left shunting of blood and prolonged expiratory time diffusion abnormalities. Cardiac disease can also lead to hypoxemia, particularly when right-to-left shunting of blood or pulmonary edema is present. Dust and cardiopulmonary diseases association is clearly stated [24-26] so that the reduction in $\%SPO_2$ among cobblestone workers was predictable.

Cardiovascular variables (heart rate and blood pressure) showed variation from their matched non exposed group and among subgroups compared to each other. The mean value±SD of heart rate in exposed groups showed very significant increment ($p=0.001$) and reduced variability compared to the non exposed group. The quarry workers heart rate mean value showed significant increment ($p=0.004$) when compared to chiseling workers. Both systolic blood pressure ($p=0.006$) and diastolic blood pressure ($p=0.001$) showed very significant increment in exposed participants. The two mean values were reduced in chiseling workers compared to quarry workers but it is not significant. Similar study depicted changes in respiratory and cardiac parameters such as an increase in the S-T segment was observed in dogs with coronary occlusion and rats after exposure to particulate

matter [13]. Chest pain at physical exertion, shortness of breath, feeling tired or weakness, tripping or racing heart, cold hands or feet, cough, phlegm, being awakened by breathing problems, wheezing, and common cold and sign in avoidance of activities have also been discussed in some studies conducted on dust exposed population[13].

Although, the exact mechanisms relating with cardiovascular changes continue to be a subject of further study, the likely means have hypothesized by various allied studies [10-12]. The first probability stated that the ultrafine dust able to evade the protective barrier lining (the epithelium) of the airways and deposited in the alveoli leading to increased blood coagulation. This mechanism operates either via pulmonary inflammation or via a direct action of ultrafine particles on red blood cells leading to sequestration of erythrocytes [1, 13-14]. Another suggestion connected with alteration of the autonomic control of the heart. Epidemiologic studies on heart rate, heart rate variability and arrhythmia showed alteration of the autonomic control [14].

Central, autonomic and hemodynamic adjustments are triggered in response to dust particles and variation of breathing patterns thereby causing both tonic and phases changes in cardiovascular functioning. This can disrupts cardiac autonomic control through sympathetic stress response and imbalance of cardiac autonomic control [9, 14]. Fine particles also indirectly stimulate the release of inflammatory cytokines in the lungs and into the circulation [9].

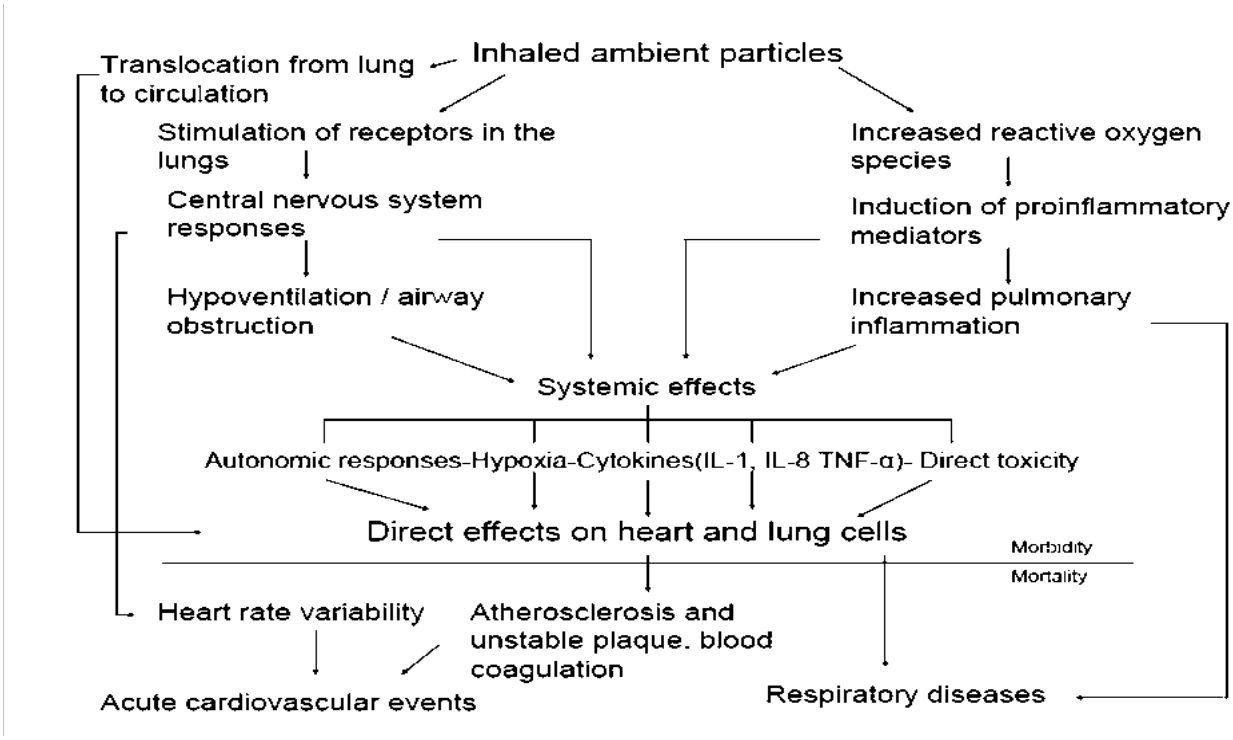

Figure 1: Hypothetical mechanisms [14]

The acute effect of dust also included $\%SPO_2$, heart rate and blood pressure. The two subgroups (chiseling and quarry groups) were taken separately in order to observe the difference. The $\%SPO_2$, showed very significant reduction (p=0.000) in both subgroups after working for 8-10 hours. While systolic blood pressure showed very

significant increment (p=0.000) in both subgroups compared to the pre shift result. Heart rate and diastolic blood pressure were higher and showed very significant rise (p=0.000) in chiseling workers. But, the increment of heart rate in quarry workers was not significant (p=0.070) and the diastolic blood pressure was increased significantly (p=0.003). As dust particles increased from moment to moment significant decrease in heart-rate fluctuation happen in response to dust and breathing rate. Short-term autonomic imbalance reflected by changes in heart rate and heart-rate variability [9].

The importance of duration of exposure shows the difference between the workers exposed for more than three years and to those exposed for below three years duration. Workers who have worked greater three year have had increased HR, systolic blood pressure and diastolic blood pressure. But the difference is not significant. Some epidemiologic studies [27, 28] have shown that increased concentrations of ambient particles are associated with cardiovascular morbidity and mortality. Hourly averaged crude effects of heart rate and blood pressure during and after exposures to concentrated ambient particle were appraised. Related studies disclosed evidence of two different effects of dust. The first effect emerged almost immediately after breathing heavy dust [11,14]. Observed characteristics indicated particulate matter intake affects a person's autonomic nervous system. The second effect confirmed only after several hours of breathing workplace dust. It showed hints of heart-rate changes due to inflammation [11].

5. Conclusion

Dust emission during cobblestone work affects the cardiovascular system. The mean value of $\%SPO_2$ was reduced significantly (p=0.030) in exposed groups compared to non exposed group. The prevalence of disease symptoms and lung function reduction were very great in chiseling workers. It affects heart rate and blood pressure. The mean value±SD of heart rate in exposed groups showed very significant increment (p=0.001) and reduced HR variability compared to the non exposed group. Both systolic blood pressure (p=0.006) and diastolic pressure (p=0.001) showed very significant increment in exposed participants.

6. Limitation of the study

The study has a number of limitations. Concentration, size, composition and dust fraction in workers breathing zone were not identified. The conventional dust and crystalline silica (quartz) emission could be diminished as it was conducted in rainy weather condition which might affect the extent of dust exposure. Selection of samples for control and exposed groups were applied only by health history information. Inclusion and exclusion procedures did not include the chest x-ray and physician’s written interpretation and explanation. Electrocardiography (ECG) was not used which might be important to predict changes (if any) in cardiac parameters and electrical activities of heart.

7. Recommendations

The concentration, composition, nature and specific effects of the dust in the work site should be studied. Subsequent studies should be done on dust effects mechanisms on cardiovascular functions. Competent authority experts should ensure the cobblestone workers are suitably informed about the hazards associated with

the cobblestone work activities. Research institutions and scholars should strengthen their investigations on the effects of dust and should give attention to hazards associated with exposure to new substances.

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