Cardio-respiratory Function among Cobble Stone Workers in Addis Ababa, Ethiopia

By

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I, the undersigned, agree to accept responsibility for the scientific and ethical conduct of the research project. This is my own original work. I assure that the study is result of my endeavor so that I would take all the responsibilities of issues related to plagiarism.

Name of the investigator: _______________________

Signature ______________________

Date____________________

Assurance of Advisor

Name of the Advisor______________________

Signature______________________

Date ______________________
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<tbody>
<tr>
<td>AAU</td>
<td>Addis Ababa University</td>
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<tr>
<td>ABP</td>
<td>Arterial Blood pressure</td>
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<td>ANOVA</td>
<td>One way analysis of variance</td>
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<td>AR</td>
<td>Attribute Risk</td>
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<td>BMI</td>
<td>Body Masss Index</td>
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<td>BP</td>
<td>Blood Pressure</td>
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<tr>
<td>bpm</td>
<td>beat per minute</td>
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<tr>
<td>cm</td>
<td>centimetre</td>
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<tr>
<td>CB</td>
<td>Chronic Bronchitis</td>
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<tr>
<td>COPD</td>
<td>Chronic Obstructive Pulmonary Disease</td>
</tr>
<tr>
<td>CVD</td>
<td>Cardiovascular Disease</td>
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<tr>
<td>CW</td>
<td>Chest Wall</td>
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<tr>
<td>DBP</td>
<td>Diastolic Blood pressure</td>
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<tr>
<td>DL,CO</td>
<td>Diffusing Capacity for Carbon Monoxide</td>
</tr>
<tr>
<td>EAD</td>
<td>Equivalent Aerodynamic Diameter</td>
</tr>
<tr>
<td>ECG</td>
<td>Electrocardiography, Electrocardiogram</td>
</tr>
<tr>
<td>FDRE</td>
<td>Federal Democratic Republic of Ethiopia</td>
</tr>
<tr>
<td>FEF25-75%</td>
<td>Forced mid expiratory flow between 25% and 75% of FVC</td>
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<tr>
<td>FEV1</td>
<td>Forced expiratory volume in one second</td>
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<tr>
<td>FEV1%</td>
<td>FEV1 to FVC ratio x 100</td>
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<tr>
<td>FVC</td>
<td>Forced vital capacity</td>
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<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
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<tr>
<td>HR</td>
<td>Heart Rate</td>
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<td>HRV</td>
<td>Heart Rate Variablity</td>
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<tr>
<td>HSE</td>
<td>Health and Safety Executive</td>
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<tr>
<td>HWE</td>
<td>Healthy Work Effect</td>
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<tr>
<td>IHD</td>
<td>International Hydrological Decade</td>
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<tr>
<td>ILD</td>
<td>Interstitial Lung Diseases</td>
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<tr>
<td>ILO</td>
<td>International labor organization</td>
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<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
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<tr>
<td>IUPAC</td>
<td>International Union of Pure and Applied Chemistry</td>
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<tr>
<td>kg</td>
<td>kilo gram</td>
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<tr>
<td>LLN</td>
<td>Lower Limits of Normal</td>
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<tr>
<td>L</td>
<td>Liter</td>
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<tr>
<td>L/s</td>
<td>Liter per second</td>
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MOLSA         Ministry of Labour and Social Affairs
NIHR, RDS    National institute for health research, Research design
NM           Neuromuscular
NOHSAC       National Occupational Health and Safety Advisory Committee
OKI          Occupational Knowledge International
OR           Odd Ratio
OSH          Occupational Safety and Health
PFT          Pulmonary Function Test
PM           Particulate Matter
PM2.5        Particles Matter with an equivalent aerodynamic diameter of up to 2.5 μm
PM10         Particles Matter with an equivalent aerodynamic diameter of up to 10μm
PPD          Personal Protective Devices
PPE          Personal Protective Equipment
RCS          Respirable crystalline silica
RR           Relative Risk
PV           Pulmonary Vascular
SBP          Systolic Blood Pressure
SPO2         Percentage of Partial Pressure of Oxygen within Arterial Hemoglobin
SEGs         Similar Exposure Groups
SD           Standard deviation
SPSS         Statistical Package for Social Sciences
SWPS         Safe Workplace Promotion Service
TB           Tuberculosis
TLC          Total Lung Capacity
TSP          Total Suspended Particles
TUC          Trades Union Congress
USEPA        United States Environmental Protection Agency
WEL          Workplace Exposure Limit
WHO          World health organization
VC           Vital Capacity
μm           micrometer
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Abstract

Background: Globally, an estimated 2.34 million people die from work-related accidents and diseases annually and 6,300 people die daily (ILO, 2013). Cobblestone work is becoming a good job opportunity in Ethiopia but it exposes workers to dust during excavating, cutting, drilling, handling, loading, transporting, chiseling and paving activities. Stone dust exposure has effect on the cardio-respiratory, liver and kidney functions with its associated symptoms as it contains metals and other substances risky for human health. Dust exposure is also associated with increased BP, reduced HR variability, increased HR, endothelial dysfunction and myocardial coronary heart disease. It induces pulmonary and systemic inflammation, accelerating atherosclerosis and altering cardiac autonomic function.

Objectives: The present study was designed to determine the prevalence and types of cardio-respiratory problems associated with effect of exposure to cobblestone dust. It was also intended to investigate acute effects of cobblestone dust exposure on cardiopulmonary function in addition to assessing the awareness of cobblestone workers about dust effect on health and practice of PPDs.

Materials and Methods: Comparative cross-sectional study and systematic random sampling was applied selecting 155 (82 chiseling and 73 quarry) workers who were 18-35 yrs old and exposed for one and above years. Twenty three of them were female chiseling workers. One hundred fifty one matched controls (128 males, 23 females) were selected from AAU summer non- smoking normal students within the same age range. Acute exposure standard was established on an eight-hour exposure time frame, during work of normal intensity and data were collected at the early morning and after exposure for about 8-10 hours. Lung function indices, HR, %SPO$_2$ and ABP were taken before and after exposure. The mean ages, height, weight and sex proportion were matching between the two groups. Questionnaire, digital spirometer, pulse oximeter, sphygmomanometer, digital balance and measuring tape were used for data collection.

Results: The study showed higher prevalence of cardio-respiratory symptoms and changes in cardiopulmonary function indices. The mean values and percent predicted mean values of lung functions (FVC, FEV1, FEV1/FVC, PEFR, PIFR and FEF25-75) were significantly reduced ($p<0.05$). The mean value of %SPO$_2$ was reduced significantly ($p=0.030$) in exposed groups compared to control. The mean value±SD of heart rate in exposed groups showed very significant increment ($p=0.001$) and reduced variability compared to the controls. Both systolic blood pressure ($p=0.006$) and diastolic pressure ($p=0.001$) showed very significant increment. Symptoms and reduction in lung function indices were more marked in chiseling workers. Neither control nor exposed group has had restrictive pattern alone; about 18.1% and 17.4% of cobble stone workers were found to have obstructive and mixed condition, respectively. In the
acute exposure study very significant changes in cardiopulmonary functions and acute symptoms were observed (p<0.010). The practice to utilize PPDs and awareness on the health impact of dust were found to be very low. Most of the workers never use PPDs for various reasons. Appropriate training has not been given. Workers complained that they were getting very limited medical treatment, scarce supply of medical equipment and drugs in the clinics. Working environment was unsafe. The present study provides essential evidences on dust impacts on health and the lack of awareness among cobblestone workers.

**Conclusion and recommendations:** From the present study, it could be concluded that dust emission during cobblestone preparation adversely affects the cardio-pulmonary function of workers. Acute exposure to dust for some hours leads very significant changes in cardiopulmonary functions. PPDs utilization and awareness about dust impact on health were very poor. It is recommended that further studies should be conducted on many workers to make standing decisions and regulations. Workers should be trained and appropriate PPEs should be accessible to them. Guideline has to be developed to provide guidance on how to assess and reduce the health impacts of dust emissions. Regular inspection should be carried out. There should be full co-operation among the competent authority, research institutions workers and occupational health professional.

**Key words:** Cobblestone, Quarry Work, Chiseling, Dust Exposure, Cardio-respiratory Function indices, Acute Effect of Dust, PPD.
1. Introduction and Review of Literature

1.1. Introduction

Cobble stone projects constitute an important construction sector in Ethiopia. The federal and regional governments have been upgrading roads within towns and cities. The project includes the quarry, chiseling and paving activities. It has been implemented almost in all towns and cities across the country. The residents have been resolving difficulties of mud and dust using cobblestones offering money for the construction of miner roads, side roads and road sides.

The cobble stone work contributes to the national gross domestic product (GDP) and becomes a good job opportunity and means of income for a good number of citizens because of many reasons. It does not require sophisticated skill, knowledge and machineries. It is labour-intensive involving a huge number of labour forces and utilizes local resources.

Cobble stone project has become one of the main concerns of Addis Ababa city administration. Offices have been organized at city and sub-city levels to coordinate the project. Currently, more than seventy thousand cobblestone workers have been engaged. Many earlier enterprises have been transiting into other businesses and have become wealthy.

During activities of cobblestone work, dust is produced and workers are exposed to dust resulting in risk on health. The cobblestone workers are exposed to dust during excavating, cutting, drilling, handling loading, transporting, chiseling and paving. The effects of Stone dust exposure on the cardio-respiratory function, liver and kidney has been well documented [1].

Many studies show occupations involving stone materials that increase the chance of stone dusts exposure which has adverse effects on health. New research published in Environmental Science and Technology [1] explained that, the dust particle in the ground is quite different from the dust that we mostly breathe. The fine dust in the underground and that from stone could have metals and other substances that are risky for human health. Therefore, health survey and study on stone dust effects has been highly useful in understanding the risks of working with ground materials and the prevalence of cardio-respiratory symptoms involved in the cobble stone works.
1.2. Occupational Safety and Health

ILO [3] defines the Occupational safety and health (OSH) the science of anticipation, recognition, evaluation and control of hazards arising from the workplace. OSH takes into account the possible impact on health of workers, the surrounding communities and the environment. Its scope has evolved gradually to social, political, technological and economic changes [4].

The ILO Safety and Health Convention in Construction (1988, No.167) and its accompanying recommendation (No.175), provides a foundation of law on which safe and healthy working conditions can be built. Effective safety management which is applying safety measures before accidents happen has three main objectives that include making the environment and the job safe as well as workers safety conscious [5].

Occupational safety and health is a key element in achieving sustained decent working conditions and strong preventive safety cultures [4]. Setting up of legal, administrative and practical procedures and frameworks for the assessment of hazards, risks and control measures are mandates of competent authorities. They have also concern on the aims and mechanisms for identifying, eliminating and controlling the hazard or risk from hazardous ambient factors. The surveillance of workers health, the working environment, the provision of information and training to workers are other attention areas [6, 7]. From the workers side, every worker is under a moral, and often also a legal, duty to take the maximum care for his or her own safety and that of fellow workers [5].

Ethiopia has committed itself to exercise International Labour Organization (ILO) Conventions. Occupational safety and health service is organized in line with the country’s federal and regional governments system that is organized in various structures. There is a memorandum of understanding signed between the federal ministry of labour and social affairs and regional bureau heads to cooperate and work jointly in occupational safety and health issues [8].

The occupational safety and health directive is a working guideline that is prepared by MOLSA getting the mandate by the proc. No 377/2000. The guideline describes the management of safe work place and occupational hazards in most occupational settings. According to the directive, occupational disease is defined as disease contacted as a result of an exposure to risk factors arising from work activity. Occupational health service is entrusted with essentially preventive functions and advising the employer, the workers and their representatives [8].
The directive addressed that, workers employed in rock excavating, loading, transporting and conveying are exposed to dust. To avoid harmful dust concentrations and to reduce dust exposure, mechanisms have been suggested in the directive. The use of water sprays, suppressing of the dust caused by drilling or handling rocks, equipments and device of acceptable type are recommended.

1.3. Occupational Diseases

An occupational disease is a disease contracted as a result of an exposure to risk factors arising from work [9]. According to the Protocol of 2002 by WHO on the Occupational Safety and Health, the term occupational disease covers any disease contracted as a result of an exposure to risk factors arising from work activity. Shaikh K. et al. [10] further defined it as illness caused by exposure to disease causing agents in the environment, as opposed to illnesses related primarily to an individual's genetic makeup or to immunological malfunctions.

There are a large number of occupational diseases linked with occupational activities that increase risk of disease or injury [11]. Driscoll T.et al. [12] described that, various cancer types, respiratory diseases, diseases of the nervous system, cardiovascular diseases, noise-induced hearing loss, vibration disorders and various causes of fatal and non-fatal injuries are the major occupational diseases and injuries. New occupational diseases, such as mental and musculoskeletal disorders are on the rise [9]. Driscoll T.et al. [12] added that, millions of workers continue to be at risk of pneumoconiosis (silicosis and asbestos related diseases) due to widespread exposures to silica, coal, asbestos and various mineral dusts in mining, quarrying, construction and other manufacturing processes. Fibrosis (e.g. asbestos, quartz), cancer (e.g. asbestos, chromates, and benzene) and irritation of mucous membranes (e.g. acid and alkalis) are the other common symptoms in occupations involving the respective chemical.

In the 2013 world day report for Safety and Health at Work [9] ILO disclosed that, globally, an estimated 2.34 million people die each year from work-related accidents and diseases. It added that, occupational diseases remain largely invisible in comparison to industrial accidents. But, studies show six times as many people die each year. According to the report, an estimated 2.02 million people die from a wide range of work related diseases. Of the estimated 6,300 work-related deaths that occur every day, 5,500 are caused by various types of work related diseases. In addition, an estimated 160 million cases of non-fatal work-related diseases have been reported annually.
Occupational diseases also impose enormous costs. It impoverishes workers and their families, reduce productivity and work capacity and dramatically increase health care expenditures. The ILO estimates [9] that work related accidents and diseases result in an annual 4% loss in global gross domestic product (GDP) or about US$2.8 trillion in direct and indirect costs of injuries and diseases.

Although, occupational diseases account for greater mortality and morbidity than occupational injuries, it is harder to diagnose measure and monitor for a range of reasons. Long latency periods after exposure, difficulties in distinguishing occupational diseases from non-occupational diseases and a lack of awareness about the occupational origins of some diseases are among others [13, 14].

Assessing workplace exposure is important not only for evaluating health risks but also for reducing exposure through workable control measures. According to Julius M., Magne B., Bente M. and Michael Y. [15], the extent to which exposure varies depends on many factors. Some are related to the agent itself, but most are linked to work content, tasks performed, production and environmental characteristics.

1.4. Occupational Cardio-respiratory Diseases

Cardiopulmonary diseases develop as result of several occupational risk factors. Numerous scientific studies have linked particle pollution exposure to increased respiratory symptoms [16]. Symptoms such as irritation of the airways, coughing, chronic bronchitis, respiratory cancers, chronic obstructive pulmonary disease (COPD), occupational asthma, pneumoconiosis and breathing difficulty through decreased lung function are the common diseases among others. Irregular heartbeat, non-fatal heart attacks and toxic effects by absorption of the toxic material into the blood could be caused by dust particles exposure [17].

William S. and Eckett B. [18] explained that the airways from nares to alveoli come into contact with 14,000 liters of air in the workplace during a 40-hour workweek. This is because of physical activities that increase ventilation. As ventilation increases, breathing shifts from nasal to a combination of oral and nasal breathing allowing a greater volume of air to bypass the cleansing nasopharynx and further increasing the exposure of the lower airways to inhaled materials. Thus, it increases exposure to contaminants up to twelve times to the level at rest.

Respiratory organs and its parts respond in various fashions depending on the nature of inhaled substances. Nasal hairs and turbinates filter particles and gases. The initial nasal mucosal response
is vascular dilation, increased permeability, rhinorrhea, and congestion. Allergens cause sneezing, itching, rhinorrhea, and congestion, whereas irritants cause burning or irritation and congestion. The larynx which has the smallest cross-sectional area in the respiratory tract forms narrows in the air stream. Air velocity increment, eddies formation and deposition of particulate matter occurs. Inflammation and edema of the vocal cords result from irritants and allergens or from the drainage of inflammatory mediators from nasal passages. Such exposures have also been associated with vocal cord dysfunction. It is a narrowing of the vocal cord aperture during inspiration that produces asthma like symptoms [18].

Soluble gases are absorbed by the upper-airway mucosa while less soluble gases enter the alveoli. The location of particle deposition in the airways is determined by the concentration and size of particles. Particles 10 μm or more in diameter are deposited in the nose and pharynx. Others 5 μm in diameter or smaller may penetrate to the alveoli. Particles of intermediate size are deposited in differing proportions at intervening levels. Categories of occupational respiratory disease, their anatomical locations within the respiratory system, examples of common causative substances and their pathophysiologic effects could be summarized in figure 1.

Figure 1. Some Occupational Respiratory Disease [18].
1.5. Physiologic Patterns of Lung function and diseases

Basic concepts of normal pulmonary physiology that are involved in pulmonary function testing include airflows, lung volumes, ventilation-perfusion interrelationship, diffusion, gas exchange and respiratory muscle strength. Pulmonary function test (PFT) determines how easily air moves in and out of the lungs, the amount of air the lungs can hold and how much oxygen the lungs send to the heart [19].

The most common and internationally standardized test is evaluation of forced expiration after a complete inhalation allowing the determination of forced vital capacity (FVC) and the forced expired volume during the first second (FEV1). Recording of the test trace is taken as a forced spirogram (volume over time) or as a flow-volume loop (flow against volume). The components of the respiratory cycle are labeled as lung volumes and lung capacities. The most important values are the forced vital capacity (FVC), the forced expiratory volume in 1 second (FEV1) and the FEV1/FVC ratio. Dozens of other parameters can be derived (Fig. 1) [20].

![Figure 2. (a) Forced spirogram and (b) flow–volume loop [20]](image)

Most individuals follow a steady trajectory of increasing pulmonary function with growth during childhood and adolescence followed by a gradual decline with aging. But, rare individuals may demonstrate steep decline. Individuals appear to track in their quartile of pulmonary function based upon environmental and genetic factors that put them on different tracks. The risk of eventual mortality from COPD is closely associated with reduced levels of FEV1 (fig. 2). Death or disability from COPD can result from a normal rate of decline after a reduced growth phase (curve C), an early initiation of pulmonary function decline after normal growth (curve B), or an accelerated decline after normal growth (curve D). The rate of decline in pulmonary function can be modified by changing environmental and genetic factors [21].
Figure 3. Hypothetical tracking curves of FEV1 for individuals throughout their life spans [21].

The normal pattern of growth and decline with age is shown by curve A. Significantly reduced FEV1 (<65% of predicted value at age 20) can develop from a normal rate of decline after a reduced pulmonary function growth phase (curve C), early initiation of pulmonary function decline after normal growth (curve B), or accelerated decline after normal growth (curve D).

The basic types of PFT patterns can in pulmonary function testing are normal, obstructive and restrictive patterns [19]. The additional pattern hyperinflation is another one. The normal pattern of growth and lung function is affected by various factors [21].

The compliance of the lung is reduced in a restrictive lung disease which increases the stiffness of the lung and limits expansion. In these cases, a pressure (P) greater than normal is required to give the same increase in volume (V). Common causes of decreased lung compliance are pulmonary fibrosis, pneumonia and pulmonary edema [22, 23].

In obstructive lung disease, airway obstruction causes an increase in resistance. During normal breathing, the pressure volume relationship is no different from in a normal lung. However, when breathing rapidly, greater pressure is needed to overcome the resistance to flow and the volume of each breath gets smaller. Common obstructive diseases include asthma, bronchitis, and emphysema while restrictive lung disease skeletal, neurologic, pleural interstitial and alveolar diseases. [22, 23].
Hyperinflation is physiologic pattern of lung function which is increasing of total lung capacity [21]. It is excessive inflation of the lungs during very deep inspiration. Hyperinflation of the thorax during tidal breathing preserves maximum expiratory airflow, because as lung volume increases, elastic recoil pressure increases and airways enlarge so that airway resistance decreases.
1.6. Dust As Airborne Particles

Airborne particles include dust, fumes, smoke or mists which suspend in the air and exist as aerosols. A fume is aerosol of solid particles formed by condensation of vapours formed at elevated temperature and less than 0.1 μm with spherical or crystalline shapes. They often rapidly coagulate, forming aggregate clusters of low overall density. Smoke is liquid droplets with diameters of less than 0.5 μm which is formed by condensation of combustion products. The third airborne particle, mist is a droplet aerosol formed by mechanical shearing of a bulk liquid droplet size. The chemical composition of airborne particles is very complex and depends on emission sources, meteorological conditions and their aerodynamic diameter. Besides the varying emission sources, PM also differs in chemical composition and size. Size properties govern the transport and removal of particles from the air; they also govern their deposition within the respiratory system and are associated with the chemical composition and sources of particles [16, 25-26].

Dust particles are generally solid and irregular in shape and have diameters greater than one μm formed by mechanical subdivision of bulk materials into airborne fines. According to the International Standardization Organization (ISO 4225 - ISO, 1994) [27], dust is small solid particle conventionally taken as below 100 μm in diameter which settle out under its own weight. The glossary of atmospheric chemistry [26] defines the term dust as small, dry and solid particles projected into the air by natural forces. These forces include wind, volcanoes, mechanical or manmade processes such as crushing, grinding, milling, drilling, demolition, shoveling, conveying, screening, bagging and sweeping. The nature and sources of dust generation may vary both in space and time. Dust arises from a range of natural and man-made (Anthropogenic) sources.

The size and chemical nature of the dust particles that determine the effect they have on the body. Larger sized particles called inhalable particles and cause nuisance impacts and irritation of the mucosal membranes [16, 27]. Smaller particles stay in the air for much longer so that it can be a danger for a longer period of time. These particles cause major health problems because these particles can pass through the lungs into other organs of the body.

From health and nuisance impact perspective, particles are commonly classified by size expressed as equivalent aerodynamic diameter (EAD) in micrometers (μm) as TSP, PM10 and PM2.5. Total suspended particles (TSP) refer to particles size with diameter ≤ 50μm. PM10 refers to dust particles with an equivalent aerodynamic diameter of up to 10 micrometers while PM2.5 refers to dust particles with an equivalent aerodynamic diameter of up to 2.5 micrometers [16].
The PM10-2.5 fraction (coarse fraction) is termed thoracic particles. These particles are inhaled into the upper part of the airways and lungs while PM2.5 particles are fine particles that are inhaled more deeply and lodge in the gas exchange region (alveolar region) of the human lung and are termed as respirable dust. These fine particles may pose a further health risk through absorption of the chemicals on the particles in the blood stream. Recent epidemiological research suggests that there is no threshold at which health effects do not occur [16, 27, 28].

1.7. Effects of Dust on the Respiratory Function

Occupational exposures to dust, fumes, and gases are associated with increased prevalence of respiratory symptoms and impairment of lung function. The emission of particulates is quite high from quarry [29, 30]. Whenever there is breakdown of sand, rocks or ores containing crystalline silica, there may be very serious hazard. It increases with the proportion of respirable particles and the free silica content of the dust. The main stone dust content is generated from granite which contains 71% silica [10]. It is most important stone type used in stone quarrying.

Any part of the respiratory tract can be adversely affected by poor air quality from the nose to the alveoli. The site affected within the respiratory tract depends on the integrity of defense mechanisms, the inherent toxicity of particles, pattern of deposition, removal from the respiratory tract and the properties of the air contaminants [31-33]. Inhaling stone dust causes the formation of lumps and fibrous scar in the lung. Stone quarry workers are at increased risk of lung and lung function effects because of their occupational exposure to silica dust [29, 34-35].

The respiratory problems [36] caused by dust exposure include chest pain, occasional cough, occasional shortness of breath and wheezing. The inhalation of dust over periods of time leads to proliferation and fibrotic changes in lungs. Severity depends on several factors including the chemical nature, physical state of the inhaled substance, the size, concentration of the dust particles, the duration of exposure and individual susceptibility. Proximity to sensitive receptors, wind direction, speed and nature of works topography influence the level of impact [37]. According to Bhagia L. [38], the respiratory system response to inhaled particles depends to a great extent on where the particle settles. The most significant reactions of the lung occur in the deepest parts. Dust particles and dust containing macrophages collect in the lung tissues, causing injury to the lungs.
1.7.1. **Silicosis**

Silica is the name of a group of minerals that are the major component of most rocks and soil. It is abundant in nature and composes about 12% of the earth’s crust [39]. The Quartz, crystalline form, is associated with human disease including silicosis, lung cancer, chronic obstructive pulmonary disease and emphysema, as well as pulmonary tuberculosis [40-42].

Silicosis [43] is a progressive, disabling lung diseases caused by breathing dust containing particles of crystalline silica. Dust particles from silica can penetrate the respiratory system and land on alveoli. This causes scar tissue in the lungs and impairs the exchange of oxygen and carbon dioxide in the blood.

The development, prevalence, latency and progression of silicosis depend on various factors [44-45]. The most important factors that influence development of silicosis include amount and kind of dust inhaled, content of crystalline free silica in the dust form of the silica, relative size of the inhaled particles, length of exposure, individual resistance, smoking habits, disease status and age of the worker [46, 47,48,49].

Signs and symptoms of silicosis include loss of fibrous lung tissue, risk of TB and autoimmune disorders like rheumatoid arthritis. Severe weight loss, extreme shortness of breath, painful cough, and bloody phlegm are also other symptoms. Reddish or bluish finger nail, ears the lips, and mental confusion, sudden fevers and chest pain could be taken as sign of the disease [35, 47]. Persons with silicosis could have an increased risk of contracting respiratory infections such as pneumonia and tuberculosis. This happens when lung cells that normally kill infectious organisms are overwhelmed by silica dust and unable to do their job [50-51].

There are three types of silicosis [52-53]. The first type is chronic silicosis which may develop due to ongoing (chronic) exposure to relatively low concentrations over a long period of time, ten or more years. The second one is accelerated silicosis that may develop five to ten years after the first exposure to high concentrations. The third type is acute silicosis develops after exposure to very high concentrations of respirable silica.

The main occupation and activities in which workers could be exposed to crystalline silica include stone crushing, farming, construction, quarrying work, rock mining and tunnel drilling stone cutting. Workers involved in activities such as sculpting, granite monuments carving, abrasive
blasting, foundry casting and tool grinding, silica flour and sand powder production, pottery, manufacturing of glass, crystal and ceramic are likely to expose to silica [27, 45, 47].

Early detection is very important because there is no cure for silicosis. A health assessment for silica-exposed workers consists of health history information, a chest x-ray, a radiologist’s report, a lung function test and a physician’s written interpretation and explanation of the assessment results [40].

1.7.2. Penetration and Deposition Mechanism of Dust Particles in Human Respiratory Regions

Dust particles small enough to stay airborne may be inhaled through the nasal route (nose) or the oral route. Dust passes through the different regions of nasopharyngeal or extra-thoracic region, trachea-bronchial region and alveolar region. The probability of inhalation depends on particle aerodynamic diameter, air movement around the body and breathing rate. The inhaled particles may then either be deposited or exhaled again, depending on a whole range of physiological and particle-related factors [7].

Tiny dust particles have the potential to penetrate the lungs and the body more easily posing a risk to the health of exposed individuals. While coarse dust is deposited in the conducting airways (nasal passages and bronchi). The fine dust can reach the bronchioles (smaller airways). It is almost exclusively the ultrafine dust which is able to reach the deepest areas of the lungs (the alveoli) where oxygen enters the blood and waste gases leave to be exhaled [1].

There are five deposition mechanisms [27]. These are sedimentation, inertial impaction, diffusion, interception, and electrostatic deposition. Sedimentation and impaction are the most important mechanisms in relation to inhaled airborne dust, and these processes are governed by particle aerodynamic diameter. There are big differences between individuals in the amount deposited in different regions.

Large particles are removed by impaction in the nose and pharynx. This means that the particles are unable to turn the corners rapidly because of their inertia, and they impinge on the wet mucosa and are trapped. Medium-sized particles deposit in small airways and elsewhere because of their weight. This is called sedimentation and occurs especially where the flow velocity is suddenly reduced because of the enormous increase in combined airway cross section.
For this reason, deposition is heavy in the terminal and respiratory bronchioles, and this region of a coal miner’s lung shows a large dust concentration. The smallest particle (PM=\(<2.5\)) reach the alveoli where some deposition occurs through diffusion to the walls. Many small particles are not deposited at all but are exhaled with the next breath [54].

Once deposited, most of the particles are removed by various clearance mechanisms. Particles that deposit on bronchial walls are swept up the moving staircase of mucus that is propelled by cilia, and they are either swallowed or expectorated. However, the ciliary action can be paralyzed by inhaled irritants. Particles deposited in the alveoli are chiefly engulfed by macrophages that leave via the blood or lymphatics [54]. Particles deposited on all but the most distal airways are removed rapidly within 24 hours by the mucociliary escalator, although a substantial proportion of particles deposited on small ciliated airways are retained for more than 24 hours. Particles that penetrate distally into the respiratory bronchioles and alveoli are cleared much less efficiently [22] (see figure 3).

Figure 6. Particulate matter (PM) deposition locations in the respiratory system [22].
1.8. Effect of Dust on the Cardiovascular System

Exposure to air pollution is an important risk factor for cardiovascular morbidity and mortality. The maximum deterioration of the lung capacity and cardio-respiratory fitness has been observed in the stone grinders. The exposure is associated with increased blood pressure, reduced heart rate variability, increased heart rate, endothelial dysfunction and myocardial ischemia [55-56]. Several studies [57, 58] in selected human samples or animal models have suggested that higher levels of ambient particles are associated with reduced heart rate variability (HRV) and coronary heart disease incidence and mortality. Breathing high concentrations of fine dust elicits changes in autonomic control of heart rhythms [59]. However, the exact the underlying biologic mechanisms linking particulate air pollution with cardiopulmonary disease continue to be a subject of research [58-60].

Recently several studies [51] have found effects on the cardiovascular diseases related to dust exposure. Exposure to fine PM increases the risk for cardiovascular mortality. The workers exposed to stone dust mostly suffer from severe lung diseases which are associated with cardiovascular complications. There is a possible association between occupational exposure to dust and ischemic heart disease [29, 61].

There is evidence that, the ultrafine dust able to evade the protective barrier lining (the epithelium) of the airways. The dust enters to the underlying tissue then to the circulation. It means the toxicity of ultrafine particles may not be limited to the airways but may involve the cardiovascular system, liver, brain, and kidneys [1, 56].

Changes in respiratory and cardiac parameters such as an increase in the S-T segment were observed in dogs with coronary occlusion and rats after exposure to particulate matter. 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[62].

It is not clear on plausible mechanism and which fraction of particulate matter is responsible for the cardiovascular effects. One hypothesis [62] is probably, ultrafine particles deposited in the alveoli lead to increased blood coagulation. This mechanism operates either via pulmonary inflammation or via a direct action of those ultrafine particles on red blood cells leading to the
sequestration of erythrocytes. An alternative hypothesis is that the cardiovascular effects are caused by alteration of the autonomic control of the heart. This theory is supported by epidemiologic studies on heart rate heart rate variability and arrhythmia. Changes in heart rate and heart rate variability were found among elderly subjects on days with elevated levels of particulate matter. These findings are supported by the results of several toxicologic studies (see figure 4).

Dust particles induce pulmonary and systemic inflammation, accelerating atherosclerosis and altering cardiac autonomic function [22]. Various central and autonomic mechanism as well as mechanical (heart) and hemodynamic adjustments are triggered in response to variation of breathing patterns thereby causing both tonic and phases changes in cardiovascular functioning.

Duanping et al [57] expounded that several hypotheses have been proposed. In view of that, cardiac autonomic control could be disrupted directly by inhaled particulates through sympathetic stress response and imbalance of cardiac autonomic control. Indirectly, fine particles stimulate the release of inflammatory cytokines in the lungs and into the circulation. Higher levels of ambient particles are associated higher heart rate, reduced heart rate variability (HRV) and coronary heart disease incidence and mortality. Landen D. et al. and Cheng et al [63-65] added that, Particulate exposure from air pollution increases the risk of ischemic heart disease (IHD) mortality.

Figure 7. Hypothetical mechanisms by which ambient fine and ultrafine particle end in morbidity and mortality [56].
Magari, S. and Christiani D. [59] distinguished a new study. Besides the higher dust concentrations the researchers recorded heart patterns for longer periods on each test day and then averaged data over different stretches of time. The study disclosed evidence of two different effects of dust. Accordingly, the first effect emerged almost immediately after breathing heavy dust. They suggested that observed characteristics indicated particulate 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. Recent studies have revealed that particulate air pollution exposure is associated with indicators of autonomic function including heart rate, blood pressure, and heart rate variability [60].
1.9. Statement of the Problem

Many studies have been conducted in different circumstances of stone dust exposure. WHO and USEPA indicate that numerous scientific studies have linked the dust particle exposure to variety of health effects. A number of studies show the effects of stone dust exposure on the cardio-respiratory function, liver and kidney. Effects on cardio-respiratory function include increased respiratory symptoms, such as irritation of the airways, chest pain, coughing, asthma, development of chronic bronchitis and breathing difficulty through decreased lung function. The maximum deterioration of lung function parameters has been observed in stone grinders [37, 65].

A new study [59] disclosed evidence of two different effects of stone dust. The first effect emerged almost immediately after breathing heavy dust. Researchers suggested that observed characteristics indicated particulate intake affects a person’s autonomic nervous system. The second effect confirmed only after several hours of breathing workplace dust. Dust exposure is associated with indicators of autonomic function including heart rate, blood pressure, and heart rate variability; increased concentrations of ambient particles are associated with cardiovascular morbidity and mortality. Dust particles induce pulmonary and systemic inflammation, accelerating atherosclerosis and altering cardiac autonomic function.

The exposure could also be associated with irregular heartbeat, endothelial dysfunction and myocardial ischemia. Premature death is recognized in people with heart or lung disease due to toxic effects of dust contents. It causes allergic or hypersensitivity effects, fibrosis, cancer and irritation of mucous membrane and gets absorbed into the blood [16].

These days, cobble stone work has been one of the main job opportunities in Ethiopia. A good number of Addis Ababa populations particularly the youth are involved in the area. Currently, about seventy thousand people have been engaged in Addis Ababa cobble stone projects.

During activities of cobble stone work, dust is produced resulting in risk on health of workers. The cobble stone workers are exposed to dust during excavating, cutting, drilling, handling, loading, transporting, chiseling and paving. It was hypothesized that the cardiopulmonary function of the exposed individuals got reduced compared to non-exposed individuals. This was why assessment was undertaken on the symptoms and disease diagnosis of the health condition of workers working with rocks and related materials.
Early detection, prevention and intervention on diseases as well as improving the working environment are the main purposes of medical surveillance. Therefore, it was timely and highly feasible conducting the present study which has explored the prevalence of cardio-respiratory symptoms and types of stone dust exposure effects. This study has identified the effects of dust exposure on the cardio-respiratory functions and the level of awareness, protective and preventive experiences.

1.10. Significance of the Study

The primary aim of the present study at workplaces is to ensure adequate workers protection and intervention on work related diseases by identifying occupational disease as early as possible. Studies linked to the dust particle exposure help assess its effects on health mainly the cardiopulmonary function.

Considering the fact that the cobble stone projects have become one of the major work options as well as the means of livelihood for many people in the city, this research would be a very important venture.

Health survey and study on stone dust effects on health has been highly useful in understanding the risks of stone dust in cobble stone works. The prevalence of cardio-respiratory symptoms involved in the cobble stone works has been identified. Awareness of the workers on the dusts effects and assessment of knowledge on ways of prevention has also been required so as to boost the preventive and protective methods and facilities. Therefore, the present research could provide input to the community and governmental and nongovernmental concerned bodies to take action desired for protecting cobblestone workers.

The results of this work may be used to help identify previously unrecognized work situations of cobble stone workers that may be in higher risk of dust inhalation. The research could also have wider implications for consideration of symptoms and diseases in future study of quarry and chiseling activities. Study outcome, literatures and observation based recommendations forwarded could have important implications.
2. Objectives

The present study was designed to attain the following general and specific objectives.

2.1. General Objective

✓ To determine the prevalence and types of cardio-respiratory problems associated with effect of dust exposure among cobble stone workers in Addis Ababa.

2.2. Specific Objectives

✓ To investigate acute and chronic effects of stone dust exposure on cardiopulmonary function among cobble stone workers.

✓ To appraise cardiopulmonary function of cobble stone workers.

✓ To evaluate the prevalence of cardio-respiratory symptoms arising from exposure to stone dust among cobble stone workers.

✓ To assess the awareness of cobble stone workers about dust effect on health and practice of PPDs.

✓ To disseminate findings relating to exposure of cobble stone workers to stone dust.
3. Materials and Methods

3.1. Study Population and Materials

3.1.1. Study Area and population

The present study was conducted in the cobble stone workers in Addis Ababa. The Sampling population was the chiseling and quarry workers which contain about 96% of the project population. They were located in eight sites namely Hana Mariam, Hidase, Bole Lemi, Gelan Gora, Legetafo, Chefea, Yeka, and Gewasa sites.

Among these sites the Hana Mariam, Chefea and Hidase sites were selected randomly and systematically considering the number of workers and duration of the establishment. Hana Mariam site has had above twenty seven thousand workers and it is located at South East of Addiss Ababa in Nifas Silk Lafto sub-city. Chefea and Hidase sites are located at North East of Addis Ababa in Bole sub-city. About ten thousand workers were engaged there.

3.1.2. Study Equipment

The present study utilized the following equipment.

A. Questionnaire - was based on British Medical Research Council questionnaire format.

B. Spirometer - A pocket sized digital spirometer called Spiro pro made by JEAGER was used to measure pulmonary function indices.

C. Pulse Oximeter - Oxi-Max N-65 hand pulse oximeter (COVIDIEN-NILLCOR and PURITAN BENNET Colorado USA) was used to record heart rate (HR) and hemoglobin saturation of arterial blood with oxygen (%SPO$_2$).

D. Sphygmomanometer and stethoscope - 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).

E. Digital balance and measuring tape were used to measure weight and height of subjects, respectively.

3.1.3. Study Subjects

The Study population was from chiseling workers (males and females) and quarry workers (only males) within an age group of 18-35 years and those worked for one year and above. Controls were selected from Addis Ababa University summer program students within the same age range and sex proportion.
3.2. Methods

3.2.1. Study Design
Comparative cross-sectional study method was applied. From a total of eight quarries and chiseling, three sites were selected based on the duration of inauguration and large number of workers. Exposure standards have been established on an eight-hour exposure time frame, during work of normal intensity to study acute effects of exposure. Data were collected in the early morning and after exposure for about 8-10 hours duration.

3.2.2. Sampling Method and Sample Size Determination
Combination of stratified random sampling and systematic random sampling methods were applied based on the sector type differing in nature of activities and sex composition. Three project sites were selected randomly and systematically considering the number of workers and duration of the establishment. The Sampling frame was taken from list of all members of the workers from the selected project coordination offices at the sites. Systematic random sampling was applied by taking the enterprises and workers profile. Sampling procedures were based on the full consent and free will of participants considering inclusive and exclusive criteria. All of the quarry workers were males while chiseling workers were both males and females.

To determine the sample size of the present study a study conducted on Dust Exposure and Lung Function Impairment in Construction Workers which was published in the Journal Physiology and Biomedical Sciences in 2011 were taken as framework [60]. Accordingly, the percent predicted value for exposed groups was 90.60% and the percent predicted value for non-exposed group was 97.37%.

Therefore, sample size could be calculated by using the following formula.

\[ n = \frac{K \times p_1(1-p_1)+p_2(1-p_2)}{(p_1-p_2)^2} \]

Where,

- \( n \) = Sample size that was taken from each exposed and non exposed group
- \( K \) = constant = 6.2 from \( f(\alpha\beta), \alpha= 0.1 \quad \beta= 0.2 \)
- \( p_1 \) = likely percent of predicted value for non exposed group=97.37 %
- \( p_2 \) = likely percent of predicted value for exposed group=90.60 %
\[
\frac{6.2 \times 0.9737 \times (1-0.9737) + 0.906(1-0.906)}{(0.9737-0.906)^2} = 151.993218 \approx 152
\]

\[n = 152\]

To increase the statistical power more, 5% of the calculated sample size value was added.

5% of sample size \(n\) = \(5\% \times 152 = 7.6 \approx 8\)

Therefore, sample size in each group = \(152 + 8 = 160\)

The number of subgroups was another consideration in the determination of a sufficient sample size. Since the parameter had to be measured for each subgroup, the size of the sample for each subgroup must be sufficiently larger to permit a reasonable estimation. Using the proportionate stratified sampling would have difficulty to compare the results of minority group sub group 1 (Quarry workers = 6.54%) with relatively larger group (chiseling workers = 93.46%). This was because the numbers achieved in the minority groups could not be large enough to give a reasonable chance of demonstrating statistical differences. To compare the study results of the minority individuals with those of the larger group, it was necessary to use a disproportionate sampling method. Therefore, the smaller category was over-sampled in order to achieve statistical power that enables to demonstrate statistically significant differences between groups. To refer the total sample as a whole representative of the wider population, the categories had become re-weight back into the proportions in which they were represented in reality.

In such studies it could be advisable that size of sample in each subgroup should have equal size [66]. So that, among the four allocation rules, equal allocation rule was applied allocating the sample size equally in all of the subgroups to obtain better precision. To do so, the following formula was used.

\[
\frac{n_h}{n} = \frac{1}{L}, \quad n_h = \frac{n}{L}
\]

\[n\] The total sample size (n=160)

\[n_h\] the sample size in subgroup h (h=1,2)

\[L\] number of subgroup (L=2)

\[n_h = n * \frac{1}{L}; \quad \frac{1}{L} = 1/2\]

1. First subgroup (Quarry workers all males)
   \[n_1 = n * \frac{1}{L} = 160 * \frac{1}{2} = 80; \quad n_1 = 80\]

2. Second subgroup (chiseling workers)
   \[n_2 = n * \frac{1}{L} = 197 * \frac{1}{2} = 80; \quad n_2 = 80; \quad N = n_1 + n_2 = 80 + 80 = 160\]
3.2.3. Inclusion and Exclusion Criteria

Selecting samples randomly from the list, the inclusion and exclusion criteria were explained exhaustively before administration of the procedures.

A. Study Subjects

*Inclusion Criteria:* Male and female workers with age range of 18-35 years who had been directly involving in quarry and chiseling works for one year and above were included in the study.

*Exclusion Criteria:* Workers with abnormalities of vertebral column and thoracic cage, anemia, diabetes mellitus, hypertension, pulmonary tuberculosis, bronchial asthma, chronic bronchitis, emphysema and other respiratory diseases were excluded. Those who had undergone abdominal or chest surgery were not allowed to participate in the study. Smokers and workers who stayed at work for less than a year were excluded.

B. Control Subjects

*Inclusion Criteria:* Male and female individuals who did not have exposure to stone dust were included. Individuals with similar age range of study subjects were included.

*Exclusion Criteria:* Workers who are exposed to stone dust and smokers were excluded. Individuals with abnormalities of vertebral column and thoracic cage, anemia, diabetes mellitus, hypertension, pulmonary tuberculosis, bronchial asthma, chronic bronchitis, emphysema and other respiratory diseases were excluded. Those who had undergone abdominal or chest surgery were excluded.

3.3. Ethical Consideration

Any activity of the present study and its results were assumed not to harm the study population in health, moral, cultural and religious reasons. Prior to data collection the principal investigator explained the purpose of the study to subjects, Addis Ababa cobblestone project coordination office officials and for other concerned bodies. Agreement was reached with Ministry of Labour and Social Affairs so as conduct the study in line with ethical principles and the Ministry of Labour and Social Affairs agreed to support the research.

Written and verbal informed consent was obtained from the project coordination office and from each participant. Participant had taken part in the study only with their consent. Brief orientations were provided throughout the procedures. The study protocol was approved by departmental ethical committee.
3.4. Data Collection Techniques and Procedures

3.4.1. Questionnaire

Questionnaires were prepared for both study and control subjects. The language of the original questionnaire was in English. But to make it clear and understandable to the participants, it was translated into Amharic. The responses were translated back into English for interpretation and statistical analysis. Occupational history, personal information and cardio-respiratory symptoms were assessed by questionnaires. Questionnaires included questions that assess attitude and knowledge of participants about stone dust exposure effects on health. Protective and preventive habits and methods of study subjects were addressed. Interviewer administered approach was used to help participants clearly understand the intention of each question.

3.4.2. Anthropometric Measurements

Weight and height were measured and used as input of subjects’ data along with cardio-respiratory functions measurement. Height of participants was measured without shoes. Weight measurement was made with light clothes nearest to one kilogram.

3.4.3. Measurement of Respiratory Function Variables

The pulmonary function tests, oxygen saturation of hemoglobin in arterial blood and heart rate of Study and control subjects were performed. Using digital Spirometry VC, FVC, FEV1, FEV1% and FEF25-75 (L/s), FEF50 (L/s), FEF25 (L/s), FEF75, PEFR and PIFR (L/S), were measured to evaluate lung volume and capacity. The study area ambient temperature, relative humidity and atmospheric pressure during measurement were obtained from national meteorology web site.

3.4.4. Measurement of Cardiovascular variables

Cardiovascular system variables (blood pressure and heart rate) were measured in both study and control groups. Mercury column Sphygmomanometer was used to measure the arterial blood pressure (ABP). It was performed by putting the left arm at the level of the heart in the sitting position. Pulse-Oxy-meter was used to measure heart rate and %SPO2.
3.5. Data Interpretation

During data organization and interpretation, age ranges of study and control subjects were grouped depending on normal capacity of cardio-respiratory function. After arrangement and organization of the data the following statistical activities were performed.

Statistical Package for Social Sciences (SPSS) for windows version 20.0 was used to analyze data while Microsoft Excel 2010 was used to arrange and organize the data.

Descriptive statistics was applied to summarize service year, job description and anthropometric measurement of subjects.

- Responses from the questionnaires was organized, summarized, analyzed, interpreted and finally compared between exposed and non exposed groups, across age groups and between subgroups.
- The Anthropometric variables, measured cardiopulmonary function were compared between exposed and non exposed subjects for each subgroup by independent sample t-test.
- The cardiopulmonary parameters were compared each subgroup by independent sample t-test.
- ANOVA was applied to check presence of significant differences in cardiovascular and respiratory system measurements of exposed subjects across different subgroups or work category.
- All of the above variables were compared across age groups.
- Prevalence of respiratory symptoms such as cough, phlegm, productive cough, breathlessness, chest pain and wheezing in both groups were analyzed by chi-square exact test.
- Paired t-test was applied to compare pre and post shift cardiopulmonary measurements.
- Prevalence of acute cardio-respiratory symptoms was analyzed by chi-square exact test.
4. Results

4.1. Demographic characteristics

Data on population characteristics were obtained as means and SDs or proportions. Tables 1, 2 and 3 show the general characteristics of the study participants. The present study involved 151 controls from AAU summer degree and post graduate diploma training (PGDT) students consisting of both males (M=128(84.1%)) and females (F=23(15.9%)). The exposed groups (N=155) were quarry (n=73(47.1%)) and chiseling (n=82(52.9%)) workers. The quarry workers were all males while the chiseling workers involved both male (M=59) and female (F=21) workers.

The mean±SD duration of years participants stayed at the cobblestone work both in quarry and chiseling was described (see table1). The mean duration of stay for quarry workers was 3.95±2.03 years while that for chiseling workers was 3.03±1.02 years.

Table 1. Job and general description of control and exposed subjects

<table>
<thead>
<tr>
<th>Controls (n=151)</th>
<th>Exposed (n=155)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Job description</td>
<td>Job description and duration of stay in the work (Mean±SD)</td>
</tr>
<tr>
<td>Summer PGDT and degree students in AAU</td>
<td>Quarry workers (3.95±2.03 years)</td>
</tr>
<tr>
<td>Male 127 (84.1%)</td>
<td>Female 23 (15.9%)</td>
</tr>
<tr>
<td>Female 23 (15.9%)</td>
<td>Chiseling workers (3.03±1.02 years)</td>
</tr>
</tbody>
</table>

Regarding educational level, 49% of the controls were diploma holders while the remaining 51% were degree holders attending PGDT Program. 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 (see table 2).

Higher proportion (64.2%) of the controls was single and 35.8% were married. Among the exposed, 54.5% were single and 40.7% of exposed participants were married. Others were divorced (4.1%) and widowed (0.7%).

Table 2. Educational and marital status of study participants

<table>
<thead>
<tr>
<th>Control (n=151)</th>
<th>Exposed (n=155)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Education</td>
<td></td>
</tr>
<tr>
<td>Diploma</td>
<td>74 (49%)</td>
</tr>
<tr>
<td>Degree</td>
<td>77 (51%)</td>
</tr>
<tr>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Elementary</td>
<td>76 (52.4%)</td>
</tr>
<tr>
<td>Secondary</td>
<td>40 (27.6%)</td>
</tr>
<tr>
<td>Tertiary</td>
<td>6 (4.1%)</td>
</tr>
<tr>
<td>2. Marital status</td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td>97 (64.2%)</td>
</tr>
<tr>
<td>Married</td>
<td>54 (35.8%)</td>
</tr>
<tr>
<td>Divorced</td>
<td>79 (54.5%)</td>
</tr>
<tr>
<td>Widowed</td>
<td>59 (40.7%)</td>
</tr>
<tr>
<td></td>
<td>6 (4.1%)</td>
</tr>
<tr>
<td></td>
<td>1 (0.7%)</td>
</tr>
</tbody>
</table>

4.2. Anthropometric measurements

Anthropometric measurements of cobble stone workers and control participants were compared (see table 3). Their calculated mean age, height, weight and body mass index (BMI) were close to each other. Mean ages of the exposed study participants (n=155) were 26.52±4.12 years and that of controls (n=151) 26.44±3.55 years. The age range of both participants was limited to 18-35 years and grouped into two so that their lung function could be compared.

The exposed group (cobble stone workers) was composed of two subgroups. The mean age of quarry workers (n=73 males) and the chiseling workers (n=82 males and females) were 27.59±3.98 and 25.56±4.02 years, respectively. The controls and each subgroup of the exposed group further grouped to age ranges (18-26 and 27-35 years).

The mean height of controls was 169.79±5.46 cm. The exposed groups height was 168.89±8.23 cm. In each age group, their respective average height was calculated as indicated in table 3.

Average weight of control and exposed group were 61.59±7.68 kg and 60.00±10.50 kg respectively. The mean calculated body mass index of controls was 21.38±2.62 kg/m² and that of the exposed groups was 20.99±3.13 kg/m². Similarly mean weight of the exposed and control across their age range was presented.
Table 3. Anthropometric measurements in both exposed and controls groups

<table>
<thead>
<tr>
<th>No</th>
<th>Group</th>
<th>Age range</th>
<th>Age years (Mean±SD)</th>
<th>Height (cm) (Mean ±SD)</th>
<th>Weight (kg) (Mean ±SD)</th>
<th>BMI(kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Controls</td>
<td>18-26(n=88)</td>
<td>26.44±3.55</td>
<td>169.79±5.46</td>
<td>61.59±7.68</td>
<td>21.38±2.62</td>
</tr>
<tr>
<td></td>
<td></td>
<td>27-35(n=63)</td>
<td>23.90±1.73</td>
<td>169.79±5.46</td>
<td>62.43±7.94</td>
<td>21.31±2.62</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>29.78±2.36</td>
<td>169.80±5.51</td>
<td>60.48±7.22</td>
<td>21.47±2.64</td>
</tr>
<tr>
<td>2</td>
<td>Exposed</td>
<td>-Quarry (n=73)</td>
<td>26.54±4.12</td>
<td>168.89±8.23</td>
<td>60.00±10.50</td>
<td>20.99±3.13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18-26(n=41)</td>
<td>30.52 ± 2.55</td>
<td>168.89±7.87</td>
<td>59.09±10.08</td>
<td>21.13±3.31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>27-35(n=32)</td>
<td>27.59±3.98</td>
<td>172.18±6.16</td>
<td>65.51±7.68</td>
<td>22.12±2.56</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>24.21±1.83</td>
<td>171.51±5.99</td>
<td>65.13±7.21</td>
<td>22.19±2.65</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30.79±2.20</td>
<td>173.03±6.37</td>
<td>66.00±8.34</td>
<td>22.04±2.48</td>
</tr>
<tr>
<td></td>
<td>-Chiseling (n=82)</td>
<td>18-26(n=47)</td>
<td>25.56±4.02</td>
<td>165.96±8.76</td>
<td>55.10±10.26</td>
<td>19.98±3.26</td>
</tr>
<tr>
<td></td>
<td></td>
<td>27-35(n=35)</td>
<td>23.20±2.01</td>
<td>165.61±8.47</td>
<td>55.36±10.09</td>
<td>20.20±3.57</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>29.93±2.89</td>
<td>166.43±9.23</td>
<td>54.74±10.61</td>
<td>19.67±2.81</td>
</tr>
</tbody>
</table>

4.3. Cardio-respiratory symptoms

The test of proportion (p) shows that, there is an association between dust inhalation and the occurrence of respiratory symptoms and diseases (see table 4). The strength of association was explained by odd ratio (OR), relative risk (RR) and attributive risk (AR) which compare the symptoms difference between exposed groups and controls as well as between subgroups.

The chi-square test indicates the presence of significantly higher prevalence of the cardio-respiratory symptoms. About 60% (OR=3.89, RR=2.16, AR=0.32) of exposed participants responded that they had experienced frequent cough. Symptoms which include Phlegm (p1=45.8, RR=1.44, AR=0.14, OR=1.81), breathlessness (p1=71, RR=2.06, AR=1.88, OR=4.67), wheezing (p1=54.8, RR=2.32, AR=0.37, AR=0.26, OR=2.95), chest tightness (P1=76.8, RR=2.77, AR=0.44, OR=6.69) and chest pain (P1=73.5, RR=3.06, AR=0.47, OR=7.69) were responded by exposed subjects. The control participants replied that cough (p2=27.8), phlegm (p2=31.8), breathlessness (p2=34.4), wheezing (p2=29.1), chest tightness (p2=33.1), chest pain (p2=26.5) were cardio-respiratory symptoms they had been noticing.
Table 4. Prevalence of cardiorespiratory symptoms of exposed and controls including RR, AR and OR with 95% CI.

<table>
<thead>
<tr>
<th>No.</th>
<th>Variables</th>
<th>Exposed (n=155)</th>
<th>Controls (n=151)</th>
<th>RR</th>
<th>AR</th>
<th>OR</th>
<th>95% CI for OR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Cough</td>
<td>93 (60%)</td>
<td>42 (27.8%)</td>
<td>2.16</td>
<td>0.32</td>
<td>3.89</td>
<td>(2.41, 6.28)</td>
</tr>
<tr>
<td>2.</td>
<td>Phlegm</td>
<td>71 (45.8%)</td>
<td>48 (31.8%)</td>
<td>1.44</td>
<td>0.14</td>
<td>1.81</td>
<td>(1.14, 2.89)</td>
</tr>
<tr>
<td>3.</td>
<td>Breathlessness</td>
<td>110 (71%)</td>
<td>52 (34.4%)</td>
<td>2.06</td>
<td>0.37</td>
<td>4.65</td>
<td>(2.87, 7.54)</td>
</tr>
<tr>
<td>4.</td>
<td>Wheezing</td>
<td>85 (54.8%)</td>
<td>44 (29.1%)</td>
<td>1.88</td>
<td>0.26</td>
<td>2.95</td>
<td>(1.84, 4.74)</td>
</tr>
<tr>
<td>5.</td>
<td>Chest tightness</td>
<td>119 (76.8%)</td>
<td>50 (33.1%)</td>
<td>2.32</td>
<td>0.44</td>
<td>6.68</td>
<td>(4.03, 11.05)</td>
</tr>
<tr>
<td>6.</td>
<td>Chest pain</td>
<td>114 (73.5%)</td>
<td>40 (26.5%)</td>
<td>2.77</td>
<td>0.47</td>
<td>7.72</td>
<td>(4.64, 12.82)</td>
</tr>
</tbody>
</table>

In the exposed groups, these cardiorespiratory symptoms were analyzed in both quarry and chiseling groups separately. Accordingly, cough (p=56.2), phlegm (p=45.20), breathlessness (p=63) wheezing (p=65.8) chest tightness (p=65.8) and chest pain (p=63) were reported by quarry workers. In the chiseling group, cough (p=63.4) phlegm (p=46.3), breathlessness (p=47.3) wheezing (p=75.6) chest tightness (p=75.6) and chest pain (p=84.1) were reported (see table 5).

The prevalence of the symptoms varied between the two separate subgroups. The rate of positive response by chiseling workers for cough (63.4%), phlegm (46.3%), breathlessness (75.6%) and chest pain (84.1%), were higher than that of the quarry workers (table 5). Wheezing (63%) and chest tightness (78.1%) rate of response in quarry workers were higher than chiseling workers which were 47.6% and 75.5%. The strength of association was explained by odd ratio (OR), relative risk (RR) and attributive risk (AR) which compares the symptoms difference between subgroups/SEGs (see table 6). The odd ratio in each comparison show the certainty how much higher prevalence occurred in a group compared within 95% confidence interval of calculated values.

Table 5. The prevalence of cardiorespiratory symptoms according to similar exposure groups (SEGs)
4.4. Respiratory Functions Measurement

Table 6 shows pulmonary function tests of the study subjects. There were statistically significant differences between the two groups in predicted and actual lung functions (FVC, FEV1, FEV1/FVC, PEFR and FEF25-75%) result (p<0.05). The cobble stone workers had lower lung function indices than controls.

The Predicted ventilatory lung function in both groups were (FVC=4.985±0.425 and 4.869±0.755; FEV1=4.136±0.328 L/s and 4.027±0.594; FEV1/FVC%=82.709±0.942 and 82.574±1.701; PEFR =9.417 ±0.732L/s and 9.215±1.261 FEF25-75%=4.343±0.303 and 4.222±0.537), respectively (p<0.005).

Table 6. Paired t-test on lung function data predicted and actual value of cobblestone workers and controls (Mean±SD)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control (n=151)</th>
<th>Exposed (n=155)</th>
<th>t-value</th>
<th>p-value</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Predicted</td>
<td>Actual</td>
<td></td>
<td></td>
<td>Predicted</td>
<td>Actual</td>
</tr>
<tr>
<td>FVC(L)</td>
<td>4.985±0.425</td>
<td>4.322±0.703</td>
<td>12.228</td>
<td>0.000</td>
<td>4.869±0.755</td>
<td>3.599±0.982</td>
</tr>
<tr>
<td></td>
<td>4.136±0.328</td>
<td>4.267±0.701</td>
<td>-2.535</td>
<td>0.012</td>
<td>4.027±0.594</td>
<td>3.524±0.850</td>
</tr>
<tr>
<td></td>
<td>82.709±0.942</td>
<td>98.940±3.412</td>
<td>-55.251</td>
<td>0.000</td>
<td>82.574±1.701</td>
<td>98.652±5.45</td>
</tr>
<tr>
<td></td>
<td>4.343±0.303</td>
<td>6.578±1.495</td>
<td>-19.373</td>
<td>0.000</td>
<td>4.222±0.537</td>
<td>6.161±1.857</td>
</tr>
<tr>
<td></td>
<td>9.417±0.732</td>
<td>8.748±2.204</td>
<td>3.954</td>
<td>0.000</td>
<td>9.215±1.261</td>
<td>8.632±2.470</td>
</tr>
</tbody>
</table>

The mean actual and percent predicted lung function measurements were analyzed by independent t-test (p<0.05). The mean percent predicted forced vital capacity (FVC) was 86.980±13.288 in controls and 74.658±19.396 in exposed groups and it was lower by 12.322. The mean percent predicted forced expiratory volume in 1 second (FEV1) was 103.596±15.883 in controls and 87.955±20.010 in exposed groups. The FEV1 was 15.64 lower in exposed groups. The mean percent predicted forced FEV1/FVC, PEFR and FEF25-75% were 119.636±4.410, 92.920±22.170 and 150.464±32.602 in controls and 119.155±7.364, 93.548±23.875 and 143.727±41.393 in exposed groups respectively. Each consecutive value was lower by 0.481, -0.6279 and 6.741 in exposed groups (see table 7).
The actual lung function indices of exposed groups and controls were compared (p<0.05) and respective t-values for each indices (table 8). The exposed groups actual indices were (FVC=75.534±0.995, FEV1=3.457±0.858, FEV1/FVC% = 98.613±5.627, PEFR=8.426±2.362 and FEF25-75=6.001±1.71). The controls actual lung function indices were (FVC=4.322±0.703 FEV1=4.267±0.701, FEV1/FVC%=98.940±3.412, PEFR=8.748±2.204 and FEF25-75=6.578±1.495)

Table 7. Lung function indices in cobblestone workers compared with controls

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Actual</th>
<th>Significance</th>
<th>Percent predicted</th>
<th>% predicted difference</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Exposed</td>
<td>t-value</td>
<td>p-value</td>
<td>t-value</td>
</tr>
<tr>
<td>FVC(L)</td>
<td>4.322±0.703</td>
<td>3.534±0.995</td>
<td>-7.983</td>
<td>0.000***</td>
<td>12.322</td>
</tr>
<tr>
<td>FEV1(L/s)</td>
<td>4.267±0.701</td>
<td>3.457±0.858</td>
<td>-9.032</td>
<td>0.000**</td>
<td>15.641</td>
</tr>
<tr>
<td>FEV1/FVC%</td>
<td>98.940±3.412</td>
<td>98.613±5.627</td>
<td>-0.614</td>
<td>0.540</td>
<td>0.481</td>
</tr>
<tr>
<td>FEF25-75(L/s)</td>
<td>6.578±1.495</td>
<td>6.001±1.715</td>
<td>-3.133</td>
<td>0.002*</td>
<td>6.741</td>
</tr>
<tr>
<td>PEFR(L/s)</td>
<td>8.748±2.204</td>
<td>8.426±2.362</td>
<td>-1.235</td>
<td>0.218</td>
<td>-0.6279</td>
</tr>
</tbody>
</table>

- Values are mean±SD
- * significant (p<0.05)
- ** highly significant (p<0.001)

After adjusting for age ranges, the exposed and control groups lung function indices were analyzed (p<0.05). The first age group (18-26) years lung function indices of the controls were (VC=3.469±0.698L; FVC=4.3001±0.763L; FEV1=4.239±0.770L; FEV1%=103.157±14.674; FEV/FVC=98.942±3.650; PEFR=8.610±2.305L; FEF25-75=6.499±1.633L and PIFR=5.180±2.368L). The same indices of the exposed groups were compare (VC=3.280±0.921L; FVC=3.686±1.034L; FEV1=3.574±0.828L; FEV1%=87.975±19.139; FEV/FVC=98.112±6.950; PEFR=8.718±2.382L; FEF25-75=6.196±1.806L and PIFR=6.434±2.608L). Very significant difference existed in FVC, FEV1, FEV1% and PIFR between the controls and exposed groups (p<0.001) (see table 8).

The lung function indices of the controls within age range 27-35 years were VC=3.509±0.601L; FVC=4.350±0.619L; FEV1=4.303±0.601L; FEV1%=81.232±1.501; FEV/FVC=98.923±3.094; PEFR=8.610±2.305L/s; FEF25-75=6.638±1.311L/s and PIFR=5.401±2.198L. While the lung
function values of exposed groups within the same age range were $VC = 3.286 \pm 0.892 \text{L}; FVC = 3.487 \pm 0.897 \text{L}; FEV1 = 3.462 \pm 0.875 \text{L}; FEV1\% = 103.508 \pm 18.274; FEV/FVC = 99.388 \pm 1.977; PEFR = 8.490 \pm 2.587 \text{L/s}; FEF25-75 = 8.490 \pm 2.587 \text{L/s}$ and $PIFR = 6.351 \pm 2.474 \text{L/s}$). Significant difference existed in $FVC$, $FEV1$ and $FEV1\%$ between the controls and exposed groups ($p < 0.001$).

Table 8. Mean and standard deviation of lung functions measurement for both control and exposed group.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Age range</th>
<th>Control (n=151)</th>
<th>Exposed (155)</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>(Mean ±SD)</td>
<td>N</td>
<td>(Mean ±SD)</td>
<td></td>
</tr>
<tr>
<td>VC(L)</td>
<td>18-26</td>
<td>86</td>
<td>3.469±0.698</td>
<td>89</td>
<td>3.280±0.921</td>
</tr>
<tr>
<td></td>
<td>27-35</td>
<td>65</td>
<td>3.509±0.601</td>
<td>66</td>
<td>3.286±0.892</td>
</tr>
<tr>
<td>FVC(L)</td>
<td>18-26</td>
<td>86</td>
<td>4.3001±0.763</td>
<td>89</td>
<td>3.686±1.034</td>
</tr>
<tr>
<td></td>
<td>27-35</td>
<td>65</td>
<td>4.350±0.619</td>
<td>66</td>
<td>3.487±0.897</td>
</tr>
<tr>
<td>FEV1(L)</td>
<td>18-26</td>
<td>86</td>
<td>4.239±0.770</td>
<td>89</td>
<td>3.574±0.828</td>
</tr>
<tr>
<td></td>
<td>27-35</td>
<td>65</td>
<td>4.303±0.601</td>
<td>66</td>
<td>3.462±0.875</td>
</tr>
<tr>
<td>FEV1%</td>
<td>18-26</td>
<td>86</td>
<td>103.157±14.674</td>
<td>89</td>
<td>87.975±19.139</td>
</tr>
<tr>
<td></td>
<td>27-35</td>
<td>65</td>
<td>81.232±1.501</td>
<td>66</td>
<td>103.508±18.274</td>
</tr>
<tr>
<td>FEV1/FVC%</td>
<td>18-26</td>
<td>86</td>
<td>98.942±3.650</td>
<td>89</td>
<td>98.112±6.950</td>
</tr>
<tr>
<td></td>
<td>27-35</td>
<td>65</td>
<td>98.923±3.094</td>
<td>66</td>
<td>99.388±1.977</td>
</tr>
<tr>
<td>FEF25-75(L/s)</td>
<td>18-26</td>
<td>86</td>
<td>6.499±1.633</td>
<td>89</td>
<td>6.196±1.806</td>
</tr>
<tr>
<td></td>
<td>27-35</td>
<td>65</td>
<td>6.638±1.311</td>
<td>66</td>
<td>6.108±1.923</td>
</tr>
<tr>
<td>PEFR(L)</td>
<td>18-26</td>
<td>86</td>
<td>8.610±2.305</td>
<td>89</td>
<td>8.718±2.382</td>
</tr>
<tr>
<td></td>
<td>27-35</td>
<td>65</td>
<td>8.868±2.094</td>
<td>66</td>
<td>8.490±2.587</td>
</tr>
<tr>
<td>PIFR(L/s)</td>
<td>18-26</td>
<td>86</td>
<td>5.180±2.368</td>
<td>89</td>
<td>6.434±2.608</td>
</tr>
<tr>
<td></td>
<td>27-35</td>
<td>65</td>
<td>5.401±2.198</td>
<td>66</td>
<td>6.351±2.474</td>
</tr>
</tbody>
</table>
The lung function mean ±SD values for both sexes and age range are presented separately (see tables 9). Lung function (VC, FVC, FEV1, FEV1, FEV1/FVC%, PEFR, FEF25-75 and PIFR) mean values for exposed males (n=74) within age range of 18-26 years were lower compared to corresponding control males (n=73) within the same age range. The lung function mean values for the exposed males (n=51) within age range of 27-35 years were similarly decreased compared to controls (n=54) except FEV1/FVC%, PEFR and PIFR that were higher in exposed participants.

The lung function indices of exposed females (n=10) within age range of 18-26 years were reduced except FEV1/FVC% compared to control females (n= 13). Peak inspiratory flow rate (PIFR) was higher in exposed females (n=11) than in controls (n=10) within 27-35 years age range while the remaining mean values were lower in exposed female participants.

Table 9. Comparison of spirometric parameters among gender and two age groups (controls and exposed)

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>Group</th>
<th>Gender</th>
<th>VC</th>
<th>FVC</th>
<th>FEV1</th>
<th>FEV1 %</th>
<th>FEV1/FVC</th>
<th>PEF R</th>
<th>FEF25-75</th>
<th>PIFR</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-26</td>
<td>control</td>
<td>Male (n=74)</td>
<td>3.50±0.65</td>
<td>4.42±0.60</td>
<td>4.37±0.61</td>
<td>105.43±13.80</td>
<td>99.01±2.97</td>
<td>8.95±2.17</td>
<td>6.65±1.45</td>
<td>11.39±52.45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female (n=13)</td>
<td>3.32±0.65</td>
<td>3.91±0.60</td>
<td>3.84±0.68</td>
<td>93.77±2.01</td>
<td>98.15±6.36</td>
<td>8.91±2.61</td>
<td>6.11±1.68</td>
<td>4.55±1.59</td>
</tr>
<tr>
<td></td>
<td>Exposed</td>
<td>Male (n=73)</td>
<td>3.42±0.89</td>
<td>3.80±1.03</td>
<td>3.68±0.79</td>
<td>87.08±18.73</td>
<td>97.79±7.60</td>
<td>8.83±2.36</td>
<td>6.21±1.86</td>
<td>6.88±2.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female (n=10)</td>
<td>2.29±0.64</td>
<td>2.75±0.52</td>
<td>2.73±0.49</td>
<td>92.90±22.59</td>
<td>99.30±2.21</td>
<td>6.94±1.14</td>
<td>5.59±1.07</td>
<td>3.94±1.73</td>
</tr>
<tr>
<td>27-35</td>
<td>control</td>
<td>Male (n=54)</td>
<td>3.48±0.62</td>
<td>4.34±0.76</td>
<td>4.28±0.73</td>
<td>104.47±18.46</td>
<td>98.96±3.38</td>
<td>8.89±1.99</td>
<td>6.81±1.47</td>
<td>5.49±2.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female (n=10)</td>
<td>3.30±0.77</td>
<td>3.99±1.02</td>
<td>3.96±1.01</td>
<td>98.40±17.24</td>
<td>99.40±0.97</td>
<td>6.53±1.94</td>
<td>5.49±1.26</td>
<td>4.29±1.83</td>
</tr>
<tr>
<td></td>
<td>Exposed</td>
<td>Male (n=51)</td>
<td>3.46±0.86</td>
<td>3.66±0.89</td>
<td>3.64±0.86</td>
<td>89.29±21.53</td>
<td>99.55±1.63</td>
<td>8.92±2.66</td>
<td>6.38±1.96</td>
<td>6.64±2.54</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female (n=11)</td>
<td>2.50±0.65</td>
<td>2.75±0.51</td>
<td>2.71±0.44</td>
<td>94.73±15.93</td>
<td>98.90±3.01</td>
<td>6.24±1.09</td>
<td>4.52±0.76</td>
<td>5.03±1.77</td>
</tr>
</tbody>
</table>

Values are mean: SD
4.4.1. Comparison of Similar Exposure Groups (SEGs)

The cobblestone male workers (quarry and chiseling) lung function values were compared (see table10). The chiseling workers lung function values were lower than that of the quarry workers. The mean±SD values of VC, FVC, FEV1 and FEF25-75 were lower in chiseling workers significantly (p<0.05). The PEFR reduction was very significant (p=0.000). The FEV1% and PIFR were also lower but not significant. Unlike other values, FEV1/FVC% was higher in chiseling workers than quarry workers. When we compare the relative reduction between PEFR and PIFR the former one was significantly reduced (p=0.000) while reduction in PIFR was not significant (0.734).

Table10. Comparison between subgroups of the Cobblestone Workers

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Quarry (n=73*) (Mean ±SD)</th>
<th>Chiseling(n=61*) (Mean±SD)</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>VC(L)</td>
<td>3.604±0.791</td>
<td>3.209±0.909</td>
<td>2.700</td>
<td>0.008</td>
</tr>
<tr>
<td>FVC(L)</td>
<td>3.912±1.008</td>
<td>3.505±0.895</td>
<td>2.425</td>
<td>0.017</td>
</tr>
<tr>
<td>FEV1(L)</td>
<td>3.812±0.804</td>
<td>3.443±0.824</td>
<td>2.591</td>
<td>0.011</td>
</tr>
<tr>
<td>FEV1%</td>
<td>90.459±20.425</td>
<td>84.262±19.333</td>
<td>1.797</td>
<td>0.075</td>
</tr>
<tr>
<td>FEV1/FVC%</td>
<td>98.493±7.053</td>
<td>98.644±3.809</td>
<td>-0.148</td>
<td>0.883</td>
</tr>
<tr>
<td>PEFR(L)</td>
<td>9.618±2.435</td>
<td>7.983±2.184</td>
<td>4.013</td>
<td>0.000</td>
</tr>
<tr>
<td>FEF25-75(L)</td>
<td>6.630±1.943</td>
<td>5.908±1.701</td>
<td>2.244</td>
<td>0.027</td>
</tr>
<tr>
<td>PIFR(L/s)</td>
<td>6.820±2.493</td>
<td>6.670±2.546</td>
<td>0.340</td>
<td>0.734</td>
</tr>
</tbody>
</table>

All are males*

Restrictive and obstructive pulmonary impairments were analyzed combining the two ATS and ITS recommendations. Restrictive pattern was identified in neither of the two groups. 4.6% and 18.1% of controls and exposed participants have had obstructive condition respectively. About 2% of controls have had mixed pattern of lung function while 17.4% of the exposed groups have had mixed condition.
Figure 8. Pulmonary impairment in cobblestone workers and controls

*—–—–: predicted flow–volume curves

* ———: observed inspiratory and expiratory flow–volume curves

Figure 9. Flow-volume curve (a, b, c, d) and volume-time curve (e) of some subjects in the present study.
4.5. Saturation of Hemoglobin in Arterial Blood

Table 13 shows the mean and standard deviation of %SPO$_2$ measurement and their corresponding t-value and p-value for both control and exposed group. Independent t-test was used to compare between control and exposed group as well as between the subgroups. There was significant difference (p=0.030) between control (mean±SD=97.272±1.306) and exposed groups (mean±SD=96.942±1.330). The difference between the two subgroup was not significant (p=0.089) although the mean value for chiseling workers was higher.

Table 11. Mean and standard deviation of %SPO$_2$ measurement for both control and exposed group

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control (n=151)</th>
<th>Exposed (n=155)</th>
<th>t-value</th>
<th>p-value</th>
<th>Quarry (n=73)</th>
<th>Chiseling (n=82)</th>
<th>Difference</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>%SPO$_2$</td>
<td>97.27±1.306</td>
<td>96.94±1.330</td>
<td>-2.186</td>
<td>0.030</td>
<td>96.92±1.313</td>
<td>97.068±1.311</td>
<td>-0.148</td>
<td>-1.382</td>
<td>0.089</td>
</tr>
</tbody>
</table>

4.6. Cardiovascular Measurement Variables

4.6.1. Blood Pressure and Heart Rate

Cardiovascular variables (heart rate and blood pressure) showed variation between exposed groups and their matched controls. There was difference between SEGs compared each other (see table 12). The mean value±SD of heart rate in exposed groups indicated very significant increment (p=0.001) and reduced variability compared to the controls. When the two subgroups (chiseling and quarry groups) mean value±SD of heart rate are compared, the quarry workers heart rate showed very significant increase (p=0.004).

Both systolic blood pressure (p=0.006) and diastolic 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.
Table 12. Mean and standard deviation of heart rate and BP measurement for both control and exposed group with their corresponding t-value and p-value of exposed and control groups.

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

4.7. Acute Respiratory Symptoms

In addition to lung function measurements to assess acute effects of dust after immediate exposure, questions were provided to evaluate the prevalence of supposed acute or immediate respiratory symptoms which might occur after working for some hours in every working day. Both subgroups of cobblestone workers were analyzed separately (see figure 1). About 39.7% of participants from quarry and 96.3% of chiseling workers reported that they had experienced acute cough after working for some hours in every working day. Respondents among quarry workers claimed that shortness of breathing (76.7%), stuffy nose (50.7%), runny nose (75%) sneezing (42.5%) and feeling of dust inhaling (45.2%) were symptoms they had noticed while they were working. The chiseling workers also reported that they had suffered from shortness of breathing (51.2%), stuffy nose (72%), and runny nose (44%) sneezing (68.3%) and feeling of dust inhaling (63.4%).
4.8. Acute Cardio-respiratory changes

Table 13 and 14 show the comparison of chronic and acute effect of dust exposure on lung function indices of both quarry and chiseling workers. Data are collected at the early morning and after expose for about 8-10 hours duration of exposure to measure the acute effect. The pre- and post measurements for each group were expressed as mean ± SD. There were statistically significant mean acute decreases in all lung function parameters following inhalation of dust. The acute effect was greater on the chiseling workers.

Table 13 shows the acute effects of dust exposure among chiseling workers. The lung function indices (VC, FVC, FEV1, FEV1%, FEV1/FVC, PEFR and FEF25-75) showed very significant decrement (p=0.000). PIFR was lower after chiseling but it was not significant (p=0.051). The mean difference between measurement results taken and scored before starting of work and after exposure (ready to home) were compared.
Table 13. Paired t test showing the difference of pre and post measured lung function indices in chiseling workers

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Chiseling Before</th>
<th>Mean difference</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>VC(L)</td>
<td>3.040±0.873</td>
<td>2.899±0.753</td>
<td>0.141</td>
<td>19.616</td>
</tr>
<tr>
<td>FVC(L)</td>
<td>3.327±0.866</td>
<td>3.135±0.753</td>
<td>0.192</td>
<td>22.326</td>
</tr>
<tr>
<td>FEV1(L)</td>
<td>3.280±0.796</td>
<td>3.126±0.751</td>
<td>0.154</td>
<td>19.870</td>
</tr>
<tr>
<td>FEV1%</td>
<td>86.750±19.450</td>
<td>80.580±18.635</td>
<td>6.170</td>
<td>32.858</td>
</tr>
<tr>
<td>FEV1/FVC%</td>
<td>98.928±3.289</td>
<td>98.221±3.743</td>
<td>0.706</td>
<td>39.344</td>
</tr>
<tr>
<td>FEF25-75 (L/s)</td>
<td>5.719±1.645</td>
<td>5.597±1.516</td>
<td>0.122</td>
<td>7.057</td>
</tr>
<tr>
<td>PEFR(L/s)</td>
<td>7.702±2.112</td>
<td>7.324±1.773</td>
<td>0.378</td>
<td>19.241</td>
</tr>
<tr>
<td>PIFR(L/s)</td>
<td>6.101±2.461</td>
<td>6.056±2.333</td>
<td>0.045</td>
<td>1.954</td>
</tr>
</tbody>
</table>

Table 14 summarizes the acute lung function response to inhaled dust. Pulmonary functions before and after quarrying were compared. They showed a significant reduction (P<0.05) in mean values of VC, FVC, FEV1, FEV1%, PEFR, FIF and FEF25-75 after working the whole day and increase in FEV1/ FVC% were compared with the values before working. Some mean values such as FVC, FEV1 and PIFR showed very significant reduction (p=0.000) while FEF25-75 and VC (P=0.001), FEV1% (p=0.010) and PEFR (p=0.003) showed significant reduction compared to the pre or morning measurement results.
Table 14. Paired t test showing the difference of pre and post measured lung function indices in quarry workers

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Quarry</th>
<th>Mean difference</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VC(L)</td>
<td>3.609±0.859</td>
<td>3.440±0.778</td>
<td>0.169</td>
<td>3.541</td>
</tr>
<tr>
<td>FVC(L)</td>
<td>3.908±1.009</td>
<td>3.724±0.969</td>
<td>0.184</td>
<td>4.609</td>
</tr>
<tr>
<td>FEV1(L)</td>
<td>3.810±0.753</td>
<td>3.585±0.687</td>
<td>0.225</td>
<td>7.885</td>
</tr>
<tr>
<td>FEV1%</td>
<td>90.315±20.529</td>
<td>88.164±18.908</td>
<td>2.151±6.901</td>
<td>2.663</td>
</tr>
<tr>
<td>FEV1/FVC%</td>
<td>98.493±7.054</td>
<td>98.877±9.416</td>
<td>-0.383</td>
<td>-0.494</td>
</tr>
<tr>
<td>FEF25-75(L/s)</td>
<td>6.658±1.946</td>
<td>6.377±1.787</td>
<td>0.280</td>
<td>3.358</td>
</tr>
<tr>
<td>PEFR(L/s)</td>
<td>9.675±2.417</td>
<td>9.207±2.473</td>
<td>0.467</td>
<td>3.026</td>
</tr>
<tr>
<td>PIFR(L/s)</td>
<td>6.759±2.431</td>
<td>6.642±2.383</td>
<td>0.117</td>
<td>5.070</td>
</tr>
</tbody>
</table>

Other Variables on which the acute effect of dust assessed include %SPO$_2$, heart rate and blood pressure. The two subgroups (chiseling and quarry groups) were taken separately in order to observe the difference between pre-shift and post-shift measurements in each sub group (see table 18). The %SPO$_2$ showed very significant reduction (p=0.000) in both subgroups after working for 8-10 hours. 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).
Table 15. Paired t test showing the difference of pre and post measured %pso2, heart rate and BP in both subgroups.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Group</th>
<th>Mean± SD Before</th>
<th>Mean± SD After</th>
<th>Mean difference</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>%SPO2</td>
<td>Quarry</td>
<td>96.548±1.281</td>
<td>95.931±1.262</td>
<td>0.616</td>
<td>4.840</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Chiseling</td>
<td>97.261±1.301</td>
<td>96.279±1.239</td>
<td>0.982</td>
<td>82.719</td>
<td>0.000</td>
</tr>
<tr>
<td>Heart rate (bpm)</td>
<td>Quarry</td>
<td>74.739±10.536</td>
<td>75.657±10.410</td>
<td>-0.918</td>
<td>-1.836</td>
<td>0.070</td>
</tr>
<tr>
<td></td>
<td>Chiseling</td>
<td>71.100±8.975</td>
<td>71.993±8.606</td>
<td>-0.893</td>
<td>-16.868</td>
<td>0.000</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>Quarry</td>
<td>112.671±9.685</td>
<td>115.726±9.205</td>
<td>-3.055</td>
<td>-4.187</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Chiseling</td>
<td>109.740±0.357</td>
<td>111.092±10.036</td>
<td>-1.352</td>
<td>-15.967</td>
<td>0.000</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>Quarry</td>
<td>74.384±7.497</td>
<td>76.644±6.564</td>
<td>-2.260</td>
<td>-3.042</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>Chiseling</td>
<td>72.195±8.696</td>
<td>73.970±8.894</td>
<td>-1.774</td>
<td>-23.584</td>
<td>0.000</td>
</tr>
</tbody>
</table>

4.9. The Workers Awareness and Practice of PPDs

The habit to utilize personal protective device is very low among the cobblestone workers. None of the respondents utilize goggle, glove, respirator and apron. Of 155 study participants, 7.1%, 9.6%, 11%, and 13.4% reported that they utilize helmet, face mask, coverall, safety shoes and other means, respectively. Out of all exposed study participants 23.08% have had habit to use any of the PPDs (see figure 7).
Exposure to dust of the manual stone workers has impact on health of workers. Dust inhalation has been correlated with number of respiratory diseases. About 58.7% of workers were aware of the impact of dust on their health. About 56.8% of workers believed exposure to dust has effect on lung and respiratory tract. While 44.5% of them think that it could cause heart problems. Additionally, 38.7%, 46.5% and 31% of workers claimed that stone dust could have effect on skin (dermatoses), eye and other health problems, respectively (see figure 8) as well.

Figure 11. The habit to use and types of PPDs supposed to be utilized.

Figure 12. The awareness of workers on the dust effect on health conditions.
Cobblestone workers require access to facilities that minimize dust hazards. The study participants were requested to respond about the access of facilities in working sites or nearer. About 12.3% of participants said they had access of personal protective devices. As far as access to training about occupational safety and hazards is concerned, 13.5% of workers agree there were access. About 2.6% of the cobblestone workers reported that they had access to medical treatment whenever diseases or injuries occurred.

Figure 13. Accesses to supposed facilities for cobblestone workers
5. Discussion

At the cobblestone working sites, workers are exposed to various dusts. The present study was designed to investigate the prevalence of symptoms and changes in cardiopulmonary function indices. It shows pulmonary function indices reduction and significant prevalence of symptoms. In the course of the study, consideration has been given to promising factors which affect the lung function such as type of work, gender, age, height, weight and BMI. Therefore, the subjects were matched for age, height and weight.

The mean duration of exposure for quarry workers was 3.95±2.03 years while it was 3.03 ±1.02 years for chiseling workers. This shows the quarry workers have been exposed to stone dust for more years than the chiseling workers.

The statistical comparisons of the matching variables (gender age, height and weight) were approximately similar for the two groups. Statistical confirmation of this fact is discussed (see Table 3) in terms of mean±SD. Participants’ age range was limited to 18-35 years and grouped into two. Mean ages of the exposed study participants (n=155) were 26.52±4.12 years while that for controls (n=151) was 26.44±3.55 years. The exposed group (cobble stone workers) was composed of two subgroups. The mean age of quarry workers (n=73 males) and the chiseling workers (n=82 males and females) were 27.59±3.98 and 25.56±4.02 years, respectively. As a person ages, the natural elasticity of the lungs decreases, so that lung volumes and capacities decline.

The mean height of controls was 169.79±5.46) cm. The exposed groups had a mean height of 168.89±8.23cm. In each age group, the respective average height was calculated as indicated in table 3. The height influences the lung size because it is proportional to chest size.

Average weight of control and exposed groups were 61.59±7.68 kg and 60.00±10.50 kg respectively. The mean calculated body mass index of controls was 21.38±2.62 while that for exposed groups was 20.99±3.13 kg/m². Similarly mean weight of the exposed and control across their age range was presented (table 3). Body size has a tremendous effect on PFT values.
A small man would have a smaller PFT than a man of the same age that is much larger because of chest to lung size proportion.

In addition to the above factors, race and geographical location may contribute to lung function indices variability. According to Yoseph A M. and Yalemtsehay M. [69], the Ethiopian men and women normal spirometric lung function test indices vary from results observed in other parts of the world. For example, mean FVC in men was 4.35 liters and 3.11 liters in women. The mean FEV1 was 3.52 liters for men and 2.45 liters in women.

Occupational exposures to dust, fumes, and gases are associated with increased prevalence of respiratory symptoms and impairment of lung function [29, 30]. The stone cutting and crushing workers are exposed to stone and other related dusts which could cause different kinds of cardio-respiratory diseases [10, 60]. The respiratory problems caused by dust exposure include chest pain, occasional cough, occasional shortness of breath and wheezing. The inhalation of dust over periods of time leads to proliferation of alveolar epithelium and fibrotic changes in lungs [10, 29, 30, 36].

In the present study, the test of proportion (p) shows there is an association between stone dust inhalation and the occurrence of respiratory disease symptoms. The prevalence of cardio-respiratory symptoms was high in cobblestone workers than in controls.

The chi-square test indicates the presence of significantly higher prevalence of the cardio-respiratory symptoms as OR and its 95% confidence interval mentioned (see table 4). About 60% (OR=3.89, RR=2.16, AR=0.32) of exposed participants stated that they had experienced frequent cough. Symptoms which include Phlegm (p1=45.8, RR=1.44, AR=0.14, OR=1.81), breathlessness (p1=71, RR=2.06, AR=1.88, OR=4.67), wheezing (p1=54.8, RR=2.32, AR=0.37, AR=0.26, OR=2.95), chest tightness (P1=76.8, RR=2.77, AR=0.44, OR=6.69) and chest pain (P1=73.5, RR=3.06, AR=0.47, OR=7.69) were experienced by exposed subjects. The proportion of each claimed symptom was above two times higher in exposed participants than in controls except phlegm which was about one and half times higher. Only this shows how many times more likely exposed participants to become diseased relative (RR) to controls.
The incidence of each symptom was highly attributable (AR) to dust exposure in cobble stone working sites. A number of studies confirmed [29, 34-35] that, Stone quarry workers are at increased risk of lung and lung function effects.

Frequencies (proportions) of cardio-respiratory symptoms among control participants (p2) were lower than that of exposed groups (p1). Cough (p2=27.8), phlegm (p2=31.8), breathlessness (p2=34.4), wheezing (p2=29.1), chest tightness (p2=33.1), chest pain (p2=26.5) were cardio-respiratory symptoms that they had been experiencing.

The strength of association between exposure and symptoms in different SEGs was explained by odd ratio (OR), relative risk (RR) and attributive risk (AR) to compare the symptoms difference between the two subgroups.

Cobble stone workers were observed and classified according to similar exposure groups (SEGs), i.e. chiseling and quarry workers. Thus, cardio-respiratory symptoms were analyzed in both quarry and chiseling groups separately (see table 5). The proportion of workers who have had the symptoms was greater in chiseling workers. The rate of positive response of chiseling workers on cough (63.4%), phlegm (46.3%), breathlessness (47.3%) and chest pain (84.1%) were higher than the quarry workers’ proportions which were 56.2%, 45.2%, 65.8%, 63%, 58.9% and 65.8%, respectively. Rate of response for wheezing (63%) and chest tightness (78.1%) in quarry workers were higher that of that chiseling workers which were 47.6% and 75.5%, respectively. The strength of association was explained by odd ratio (OR), relative risk (RR) and attributive risk (AR) which compare the symptoms difference between subgroup /SEGs (see table 5). The odd ratio in each comparison shows the certainty on how much higher prevalence occurred in a group compared within 95% confidence interval of calculated values.

The prevalence of the symptoms variation between the two subgroups (SEGs) could have possible reasons. The chiseling workers were mostly working in shade while quarry workers work in open space with better ventilation. This condition could account for the greater prevalence of symptom among chiseling workers. Previous published work [70] explained that air movement extent has a great deal of variability effect of dust on health. Similar exposed groups (SEGs) in
enclosed and air controlled work environments typically experience lower air movement compared with SEGs working outdoors. Thus, it increases the dust concentration which in turn increases the potential for risk of inhaling much more respirable dust and quartz. The other factor probably could be the proximity of workers respiratory parts to the stone being chiseled producing various size dust particles. It might make sense that the nature of chiseling work activities requires intense contact with stones increasing the probability of higher exposure.

Other likely reason could be the level of work load. The quarry workers have had machinery support while the chiseling workers don not. Therefore, the higher the workload the higher the breathing rate so that more dust is inhaled. Thus, tasks involving heavy physical work will entail greater dust inhalation because the amount of dust inhaled depends on the lung ventilation rate [69].

The respiratory problems caused by dust exposure include chest pain, occasional cough, occasional shortness of breath and wheezing. The inhalation of dust over periods of time leads to proliferation and fibrotic changes in lungs. Severity depends on several factors including the chemical nature, physical state of the inhaled substance, the size, concentration of the dust particles, the duration of exposure and individual susceptibility. Proximity to sensitive receptors, prevailing wind direction, speed and nature of works topography influence the level of impact [37].

The advent of pulmonary function tests have opened a new era towards the scientific approach in diagnosis, prognosis and management of bronchopulmonary disorders. Normal cardiopulmonary functions could be altered by external factors like occupational dust exposure resulting cardio-respiratory function impairments. Many studies have been done in relation to pulmonary functions both in normal subjects and in workers exposed to different occupation dust hazards. Yoseph A. M. and Asrat B. [71] explained that quite a lot of data are indicative of the association between the progressive decrease in values of pulmonary function indices and exposure to dust particles as reported by many other researchers.
The present study depicted a similar trend on the dust effects on lung function. Table 6 summarizes the comparison of lung function between exposed groups and that of controls. There was significant difference between the two groups in both mean values and the percent predicted values of the lung function (FVC, FEV1, FEV1/FVC, PEFR and FEF25-75%) result (p< 0.05). The cobblestone workers had lower lung function indices than controls.

Cobblestone workers exposed to dust showed a significant reduction in percent predicted values and mean values of FVC and FEV1 when compared with their matched controls (see Table 7). But, these workers did not show a statistically significant reduction in FEV1/FVC% and PEFR relative to controls. The actual mean FEF25-75 in the cobblestone workers was decreased significantly, but the reduction in percent predicted values data relative to controls was not significant. For instance, the mean predicted FEV1 (14.267±0.701) in controls was greater than that of exposed groups (FEV1=3.457±0.858). This result probably implies that the actual and percent predicted lung function indices of exposed workers were reduced by dust exposure.

Larger particles such as sand may become trapped in the nose and throat but can be expelled by coughing or sneezing. Very small, fine particles may cause more serious health problems because they can be inhaled deep into the lungs and airways. These extremely small particles and liquid droplets can include acids, chemicals, metals, soil or dust [72].

After adjusting the age ranges of the exposed and control groups, lung function indices were analyzed to be significantly different (p<0.05) (see table 8). Control participants grouped in the first age range (18-26) years compared with the exposed groups of the same age range lung function indices. The second age groups of lung function indices in both controls and stone workers were compared. Significant reduction in mean values of FVC, FEV1, FEV1% and PIFR was obtained in exposed groups of both age ranges compared to controls (p<0.05). The mean values of VC, FEV/FVC%, PEFR and FEF25-75% of the exposed groups within second age range (27-35) years were reduced but not significant. The study found that, lung function index changes in the lung function observed in cobblestone workers were caused by continuous exposure to the dust where in line with the findings of the others [1, 2, 71-73].
The means±SD of the lung function indices show discrepancy among the exposed groups and controls when categorized based on age range and gender. It could be possible to see the difference in both sexes separately (see table 9). It is clearly indicated that, the lung function indices of respective gender of participants within age range of 18-26 years were greater compared to similar age range of exposed participants. Mengesha Y.A and Mekonnen Y. [69] described that, Ethiopian normal lung function indices within age range of 18-27 years were different compared to those within 28-37 years age range in both sexes. The lung function indices for males within age range of 18-27 years were FVC=4.60±0.67L, FEV1=4.09±0.55L, FEV1%=89.04±5.66 and PEFR=9.33±1.67L. The males within age range of 28-37 years had FVC=4.57±0.82L, FEV1=3.79±0.76L, FEV1%=82.79±5.04 and PEFR=8.87±1.13L which were lower compared to former ones. Lung function mean values for the females of age range 18-27 years were FVC=3.16±0.42L, FEV1=2.65±0.39L, FEV1%=83.89±7.76 and PEFR=6.76±0.9L were lower from those with age range 28-37 years (FVC=3.04±0.53L, FEV1=2.49±0.39L, FEV1%=81.76±7.18 and PEFR=6.50±0.94L).

The results of exposed groups in the present study were compared with that of the previous study. Some lung function indices were higher than results of previous study which was supposed to be lower. PEFR for males within age group of 27-35 and PEFR for females within age range of 18-26 years were higher for exposed groups within similar age range. This contradiction might arise from the differences in anthropometric measurements like height, weight and BMI. It could be also as result of technical errors which were confirmed to be 3–10% in standardized tests [20].

The exposed males (n=74) within age of range 18-26 years with mean values of lung function indices (VC, FVC, FEV1, FEV1, FEV1/FVC%, PEFR, FEF25-75 and PIFR) were lower when compared with corresponding control males (n=73) within the same age range. The exposed males’ (n=51) mean values of lung function within age range of 27-35 years were similarly decreased compared to control (n=54) except FEV1/FVC%, PEFR and PIFR which were higher in exposed participants.
The lung function indices of exposed females (n=10) within age range of 18-26 years were reduced except FEV1/FVC% when compared to control females (n= 13) with the same age range. Peak inspiratory flow rate (PIFR) was higher in exposed females (n=11) than in controls (n=10) within 27-35 years age range while the remaining mean values were lower in exposed female participants of this age range (see table 9).

Results from lung function measurement of both cobblestone workers and controls were as predicted in the hypothesis. But, some mean values deviate from the fact. For example, in the 27-35 years age range of males, FEV1/FVC% (99.55±1.63), PEFR (8.92±2.66) and PIFR (6.64±2.54) were higher in exposed groups than controls (98.96±3.38, 8.89±1.99 and 5.49±2.09), respectively. PIFR(5.03±1.77L) was also higher in exposed females (n=11) than in controls (4.29±1.83L) (n=10) within 27-35 years age range (see table10). A similar condition was observed in a study conducted on sweepers in India [70]. In that study sweepers showed a significant reduction in mean values and percentage predicted values of FVC, FEV1, PEFR and FEF 25-75 as compared to their matched controls, but these workers showed a statistically significant increase in FEV1/ FVC% relative to controls. As it is mentioned earlier, this might be because of differences in anthropometric measurements or due to technical errors.

The lung function values (VC, FVC, FEV1, %FEV1/FVC and PEFR) of male workers in both sub groups (quarry and chiseling) were compared one to the other (see table10). The lung function values of chiseling workers were lower than the quarry workers. This result could indicate the impact of dust on lung function of chiseling worker like the frequency of the symptoms. The mean±SD values of VC, FVC, FEV1 and FEF25-75% were significantly (p<0.05) lower in chiseling workers. The PEFR reduction was very significant (p=0.000). The FEV1% and PIFR were also lower but not significant. Unlike other values, FEV1/FVC% was higher in quarry workers than in chiseling workers (p=0.883).

The likely justification for the difference has been mentioned above. To recall briefly, the chiseling workers were very proximate to the dust. They have done the chiseling without machinery support and the nature of the work activities increase the potential of risk to exposure.
Another probability could be the body size. Quarry workers were a bit bigger in height and weight than chiseling workers although it was tried to match BMI (22.12±2.56 and 20.21±2.54), respectively. This might be reflecting on lung function and justify the discrepancy.

Pulmonary impairment in cobblestone workers and controls were interpreted to assess the severity of occurrence of the obstructive and restrictive or mixed conditions (see figure 8). Pulmonary impairment conditions of the present study participants were analyzed combining the two ATS and ITS recommendations. Accordingly, About 4.6% and 18.1% of controls and exposed participants respectively have had obstructive condition respectively. About 2% of controls have had mixed pattern of lung function while 17.4% of the exposed groups have had mixed condition. Neither control nor exposed group has had restrictive pattern alone. There was great lung function pattern difference between the groups. From the result, it could be stated that, the dust effect on lung function is on both airways and lungs.

Interpretation of PFTs is usually based on comparisons of data measured in an individual patient or subject with reference (predicted) values based on matched healthy subjects. It also involves recognizing the pattern of Volume-time and flow-volume curve abnormality (see figure 9) [20]. To classify as the obstructive, restrictive, or normal pattern, the first step could be to evaluating the FEV1/FVC ratio. If this ratio is less than the lower limit of normal (=<70%), it shows the FEV1 has fallen to a greater degree than the FVC indicating presence of an obstructive defect. If this ratio is greater than the lower limit of normal, then either the spirometry test is normal or a restrictive defect is present. The next step is to look at the FVC. If the FVC is less than the predicted lower limit of normal (=<70%), it verifies the presence of restriction. If FEV1% become beyond 90% it is indicative for restrictive condition. If both FEV1/FVC ratio and percent predicted FVC values are within 70-90%, this indicates normal condition [19, 20, 74].

A mixed ventilatory defect is characterized by the coexistence of obstruction and restriction and is defined physiologically when both FEV1/FVC and FVC are below the 5th percentiles of their relevant predicted values. Since FVC may be equally reduced in both obstruction and restriction, the presence of a restrictive component in an obstructed patient cannot be inferred from simple measurements of FEV1 and FVC. One can state that the FVC was also reduced, probably due to
hyperinflation, but that a superimposed restriction of lung volumes cannot be ruled out. Conversely, when FEV1/VC is low and FVC is normal, a superimposed restriction of lung volumes can be ruled out [24].

Hemoglobin (Hb) is oxygen transporting protein in the blood which is composed of four polypeptide chains each containing one heme (iron ion). Each hemoglobin binds with four oxygen molecules. In humans, the average hemoglobin concentration is 16g/100 ml of blood. Iron releases the oxygen outside of the lungs because of an equilibrium factor. Oxygen is abundant in the lungs and the equilibrium shifts to the right. In the tissues, the equilibrium shifts to the left releasing oxygen from the complex [75].

Table 11 shows the mean and standard deviation of %SPO2 measurement for both control and exposed group with their corresponding t-value and p-value. There was significant reduction in exposed groups (mean±SD=96.942±1.330) compared to control (mean±SD=97.272±1.306) (p=0.030). The difference between the two subgroups was not significant (p=0.089) although the mean value for chiseling workers was higher.

The PO2 in the lungs capillaries is 100 mm Hg and Hb is almost completely saturated with oxygen under normal circumstances. Since the PO2 of blood cannot change until the blood reaches the capillaries in the tissues, all arterial blood is expected to be just about 100% saturated. As it reaches to the tissues, the partial pressure of oxygen (PO2) decreases leading to reduction in the percent saturation. When blood is leaving the tissues, 70% saturation is the typical %SPO2 in the capillaries of resting tissues [75].

Oxygen binding to hemoglobin is determined by the partial pressure of oxygen (SPO2), PH and hemoglobin concentration. Oxygen tension, temperature and organic phosphate also affect it [68]. William E. H. and Alexander K. [76] described hypoxemia could cause low oxygen saturation (SPO2) on pulse oximetry secondary to pulmonary disease. 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 [9, 29, 31, 36] so that the reduction in \%SPO_2 among cobble stone workers was predictable.

Exposure to ambient particles is an important risk factor for cardiovascular morbidity and mortality. The exposure is associated with increased blood pressure, reduced heart rate variability, increased heart rate, endothelial dysfunction and myocardial ischemia [56-57 62-62]. Breathing high concentrations of fine dust elicits changes in autonomic control of heart rhythms [57]. However, the exact underlying biologic mechanisms linking particulate air pollution with cardiopulmonary disease continue to be a subject of research [59-62].

Cardiovascular variables (heart rate and blood pressure) showed variation from their matched controls and among subgroups compared to each other (see table 12). The mean value±SD of heart rate in exposed groups shows very significant increment (p=0.001) and reduced variability compared to the control. The quarry worker heart rate mean value showed very significant increase (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.

The present study investigated the acute effect of dust exposure by assessing the acute respiratory symptoms and measuring the cardiopulmonary function. Exposure standards have been established on an eight-hour exposure time frame during work of normal intensity. After immediate exposure, questions were provided to evaluate the prevalence of supposed acute or immediate respiratory symptoms which might occur after working for some hours in every working day.

Based on similar exposure groups (SEGs) both subgroups of cobblestone workers were assessed separately (see figure 10). About 39.7% of participants from quarry and 96.3 % of chiseling workers stated that they had experienced acute cough after working for some hours in every working day. This indicates that the chiseling workers were very highly exposable to the dust. Respondents among quarry workers claimed that shortness of breathing (76.7%), stuffy nose
(50.7%), runny nose (75%), sneezing (42.5%) and feeling of dust inhaling (45.2%) were symptoms they had noticed while they were work. The chiseling workers were also reported that they had suffered from shortness of breathing (51.2%), stuffy nose (72%), runny nose (44%), sneezing (68.3%) and feeling of dust inhaling (63.4%).

The study results show immediate (acute) shortness of breathing and runny nose were more prevalent in quarry workers than in chiseling workers. The chiseling workers have had higher possibility of sensing the dust being inhaled. It could probably be a result of either higher proximity or greater amount and concentration of dust emission. Similar study showed that sweepers in India had had more significant respiratory symptoms like sneezing, stuffy nose, running nose and shortness of breath after sweeping for some hours [73].

The acute lung function changes were also studied in the present study. The pulmonary function tests were carried out before starting the work and after 8 hours of exposure to dust. Tables 13 and 14 summarize the acute lung function response to inhaled dust in both chiseling and quarry workers, respectively. Pulmonary functions before and after chiseling or quarrying was compared. They showed a significant reduction in mean values of VC, FVC, FEV1, FEV1%, PEFR and FEF25-75% after chiseling or quarrying for about 8 hours.

The lung function indices (VC, FVC, FEV1, FEV1%, FEV1/FVC, PEFR and FEF25-75%) showed very significant decrement (p=0.000) in chiseling workers. PIFR was lower after chiseling but it was not significant (p=0.051). When we see the quarry workers, mean values such as FVC, FEV1 and PIFR showed very significant reduction (p=0.000) while FEF25-75% and VC (P=0.001), FEV1% (p=0.010) and PEFR (p=0.003) also showed significant reduction compared to the pre or morning measurement results. Pulmonary functions before and after quarrying were compared. After working 8-10 hours, mean value of FEV1/FVC% was increased compared with the values before working. A study on effect of acute exposure to different occupational dusts in Ethiopia [77], found that significant difference between the post shift and pre shift values of lung functions in factory workers. A number of subjects showed reduction in many of the lung function indices in response to acute exposure to cotton-yarn, tobacco and cement dusts. Similar study on acute respiratory effect of dust exposure in sweepers conducted
in India found a relationship between the exposure and acute response of lung to the dust and they also observed a significant decrease in the after mean values and predicted mean values [73].

To the best of investigator is acknowledged, the present study was the first study that had been carried out in Ethiopia on the effect of dust on cardiopulmonary functions of cobble stone workers. The study on acute effects showed a statistically significant decrease in the lung mean values in post shift compared to pre shift measurement values. The study showed more significant reduction in pulmonary functions indices in chiseling workers as compared to quarry workers.

This result suggests exposure to dust causes acute decrease in lung function. The major significance of evaluating the acute changes in lung function parameters of cobblestone workers is that the individuals who are more susceptible can be identified. Medical surveillance of early detection can contribute to reducing the burden of lung function impairments.

The acute effect of dust also included %SPO₂, heart rate and blood pressure. The two subgroups (chiseling and quarry groups) were taken separately in order to observe the difference (see table 15). The %SPO₂ 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 [57].
Epidemiologic studies [64-65] 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. Magari, S. and Christiani D [59] disclosed evidence of two different effects of dust. The first effect emerged almost immediately after breathing heavy dust. They suggested that 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.

HSE [45] stated that, the occupation itself may not be entirely responsible for low values of cardiopulmonary function variables. Some other factors such as duration of exposure, poverty, prolonged stay, fatigue and absence of protective measures escalate the problem. Malnutrition and inefficient medical health checkup must also have contributed to these values. Therefore, measures should be taken to prevent the hazardous effects of different dusts in occupations that emit dust so as to provide healthy conditions for the workers.

Limited number of studies was done regarding knowledge, awareness and practice of personal protective devices/equipment used by workers exposed to hazardous dust and chemicals. A study by Mekonnen Y. and Agonafir T. [78] entitled Personal Protective Equipment use by farm workers in Ethiopia, indicated PPE use was not properly regulated and provided for the workers who had been handling hazardous pesticides and insecticides. They added that, workers were reluctant to regularly use of PPE and worn out PPE in some cases was in use rendering no protection.

In the present study the practice to utilize personal protective device was very low among the cobblestone workers. None of the respondents utilize goggle, glove, respirator and apron. Proportions of workers like 7.1%, 9.6%, 11%, and 13.4% of participants said they utilize helmet, face mask, coverall, safety shoes and other local means, respectively. Out of all exposed study participants 23.08% have had habit to use any of personal protective devices and equipment (see figure 11). This indicates that the practice and utilization of PPDs and PPEs were very low.
Exposure to dust of the manual stone workers has significant impact on health. Dust inhalation has been correlated with number of respiratory diseases. A worker should know the selection, maintenance and use of personal protective equipment and should have awareness of the kinds of diseases and injuries identified in previous studies.

In the present study of 155 workers, 58.7% workers have had awareness about the impact of dust on their health. About 56.8% workers believed that exposure to dust has effect on lung and respiratory tract while 44.5% of them thought it could cause heart problems. About 38.7%, 46.5% and 31% of workers claimed that stone dust could have effect on skin, eye and other health problems, respectively (see figure 12). The study in general shows the very limited knowledge and awareness among workers about stone dust effects on different parts of the body. The present study results agreed with other findings. For example, Mengesha Y.A. and Bekele A. [77] depicted that awareness about occupational hazards among factory workers in Ethiopia is limited.

Cobblestone workers require access to facilities that minimize dust exposure and resulting hazards. The study participants were requested to respond about the access of facilities in working sites or nearer. Of 155 cobblestone workers 12.3% participants said they had access to personal protective devices. As far as access to training about occupational safety and hazards is concerned, only 13.5% of workers agreed there were access. Whenever diseases or injuries occurred at working site, about 2.6% of the workers agreed that they had appropriate access to medical treatment (see figure 13). This shows the inadequate and scarce access to awareness creation, training and limited supply of PPDs for the cobblestone workers. Health care providers were recruited in each cobblestone work sites but, most workers claimed that there were not drugs, necessary medical equipments and better first aid implements. They added that the only heath services that were provided included wound wash and bandage, paracetamol as well as condoms.

Practically, the action of concerned bodies in the safety and health of workers is very limited in Ethiopia. A study [77] on factory workers explained that, the surveillance of work environment in the factory workers was either inadequate or lacking. There were neither regular medical check-ups nor proper protection of workers against adverse occupational hazards.
6. Conclusion

From the present study it is concluded that dust emission during cobblestone work adversely affect the cardio-pulmonary function. The study shows higher prevalence of cardio-respiratory symptoms and decrease in pulmonary function indices among the workers. Dust from stone works has also effect on heart rate, %SPO$_2$, and blood pressure.

The mean values and percent predicted mean values of lung functions (FVC, FEV1, FEV1/FVC, PEF and FEF25-75%) were significantly reduced (p< 0.05). The mean value of %SPO$_2$ was reduced significantly (p=0.030) in exposed groups compared to controls. The mean value±SD of heart rate in exposed groups showed very significant increment (p=0.001) and reduced HR variability compared to the control. Both systolic blood pressure (p=0.006) and diastolic pressure (p=0.001) showed very significant increment in exposed participants.

The prevalence of disease symptoms and lung function reduction were very great in chiseling workers. The possible reasons could be working in shade, proximity of respiratory parts to dust, dust quantity and higher workload. Although the quarry work requires greater effort, the workers were supported by machines and had break time unlike chiseling workers.

Based on combined criteria of ATS and ITS, pulmonary impairment in exposed group was higher. Neither control nor exposed group has had restrictive pattern alone. About 18.1% and 17.4% of the workers participated in the study have had obstructive and mixed condition respectively.

The study showed higher prevalence of acute cardio-respiratory symptoms. The acute exposure to dust caused a significant reduction in the respiratory performance. The results indicate that acute exposure to dust for some hours promote very significant changes in cardiopulmonary functions.

The habit to utilize personal protective device and awareness on the health impact of dust were very low among the cobblestone workers. Most of the workers never use PPDs for various reasons. Lack of awareness, inadequate supply and access of facilities were reasons given.
Significant number of workers did not know the likely health trouble of dust on different parts of their body. Appropriate training about occupational safety and hazards has not been given properly. Although health professionals were assigned, workers were not satisfied because of very limited medical treatment, scarce supply of medical equipment and drugs in the clinics. As far as the working environment was concerned, it was unsafe. During data collection the investigator observed frequent physical injuries on body parts and heard some death cases.

Generally, the present study provides essential evidences on the implication of stone dust impacts on health and on the level of awareness among cobblestone workers in Ethiopia particularly in Addis Ababa.
7. Limitation of the Study

The present study has a number of limitations. There is limited knowledge on the concentration, composition, nature and specific effects of the dust in the work site. Dust sampler and dust sizer should have been used. The respirable dust fraction in the worker’s breathing zone and size distributions of particle number were not measured. The study was conducted in the rainy weather condition. Thus, conventional dust and crystalline silica (quartz) emission could be diminished 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. The cobble stone work activities includes quarry, chiseling and paving. But the study did not include paving workers although the level of dust exposure might be lower compared with the two sectors.

Electrocardiography (ECG) was not used. It might be important to predict changes (if any) in cardiac parameters and electrical activities of heart (arrhythmia, myocardial infarction, coronary artery bypass, and stroke). Another limitation of the study was it did not include all age groups. It was limited to study participants within age range of 18-35 years. It was because of the age variability in exposed groups. Almost age of all chiseling workers was below 35 years. The quarry workers were only males. Thus, it was difficult to compare the difference between subgroups.
8. Recommendations

The protection of workers’ health against the occupational hazards at the workplace should be the concern of all of those involved in the design, organization and performance of the work and the protection of workers’ health. Thus, from the present study it is recommended that:

- Workers should be trained to understand the hazards associated with dust.
- Modern technologies such as engineering controls should be applied to reduce the risks.
- Workers need to get access of appropriate PPDs, protective clothing and safety shoes.
- Dust control measures such as wetting the surface reduces acute respiratory health hazards.
- Assessment (keeping writing records of the workers health condition) including periodic assessment of pulmonary function has to be done as possible.
- Workers are not advised to eat, drink and apply cosmetics in areas where dust is present.
- Subsequent studies should be done on dust effects mechanisms on cardiopulmonary functions.
- Compositions and concentrations and size of stone dust at various sites should be studied.
- Some worker may need to arrange to be placed under health surveillance including health and working history questionnaires, lung function tests and chest X-rays.
- Occupational health professionals should be recruited for the cobble stone workers.
- Effective legal and administrative frameworks for the prevention and reduction of hazards and risks should be developed in addition to the existing ones.
- Guideline has to be been developed to provide guidance on how to assess and reduce the health and environmental impacts of dust emissions.
- Competent authority experts should ensure the cobblestone workers are suitably informed of the hazards associated with the cobblestone work activities.
- to protect their own health as well as that of their colleagues
- Workers should abide by any instructions given to them about hazards and injuries to protect their own health as well as that of their colleagues
- 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.
- There should be full co-operation at all levels between the competent authority, research institutions, employers, workers and their representatives and occupational health professional.
9. References


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10. Appendices

Appendix 1: List of rock chemical compositions from which stone are formed

Table 16. Rock forming minerals and their chemical composition.

<table>
<thead>
<tr>
<th>Mineral and elements</th>
<th>Approximate chemical composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plagioclase Feldspar</td>
<td>NaAlSi$_3$O$_8$ to CaAl$_2$Si$_2$O$_6$ (continuous series)</td>
</tr>
<tr>
<td>Potassium Feldspar</td>
<td>KAlSi$_3$O$_8$</td>
</tr>
<tr>
<td>Quartz</td>
<td>SiO$_2$</td>
</tr>
<tr>
<td>Pyroxene</td>
<td>(Mg,Fe)$_2$Si$_2$O$_6$ (enstatite series) and (Ca,Na) (Mg,Fe,Al,Ti,) (Si,Al)$_2$O$_6$ (augite)</td>
</tr>
<tr>
<td>Biotite</td>
<td>K(Fe,Mg)$_3$AlSi$<em>3$O$</em>{10}$(OH)$_2$</td>
</tr>
<tr>
<td>Muscovite</td>
<td>KAl$_2$(Si$<em>3$Al)O$</em>{10}$(OH,F)$_2$</td>
</tr>
<tr>
<td>Hornblende</td>
<td>(Ca,Na)$_2$·3(Mg,Fe,Al)$_3$<a href="OH">(Si,Al)$<em>6$O$</em>{22}$</a>$_2$</td>
</tr>
<tr>
<td>Olivine</td>
<td>(Fe,Mg)$_2$SiO$_4$</td>
</tr>
<tr>
<td>Calcite</td>
<td>CaCO$_3$</td>
</tr>
<tr>
<td>Dolomite</td>
<td>CaMg(CO$_3$)$_2$</td>
</tr>
<tr>
<td>Cinnabar</td>
<td>HgS</td>
</tr>
<tr>
<td>Galena</td>
<td>PBS</td>
</tr>
<tr>
<td>Pyrite</td>
<td>FeS$_2$</td>
</tr>
<tr>
<td>Fluorite</td>
<td>CaF$_2$</td>
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<tr>
<td>Halite</td>
<td>NaCl</td>
</tr>
<tr>
<td>Corundum</td>
<td>Al$_2$O$_3$</td>
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<td>Cuprite</td>
<td>Cu$_2$O</td>
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<tr>
<td>Hematite</td>
<td>Fe$_2$O$_3$</td>
</tr>
<tr>
<td>Malachite</td>
<td>Cu$_2$(CO$_3$)(OH)$_2$</td>
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<tr>
<td>Anhydrite</td>
<td>CaSO$_4$</td>
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<tr>
<td>Gypsum</td>
<td>CaSO$_4·3$(H$_2$O)</td>
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<tr>
<td>Apatite</td>
<td>Ca$_5$(F,Cl,OH)(PO$_4$)</td>
</tr>
<tr>
<td>Albite</td>
<td>NaAlSi$_3$O$_8$</td>
</tr>
<tr>
<td>Augite</td>
<td>Ca, Na(Mg, Fe,( Al)(Al, Si)$_2$O$_6$</td>
</tr>
<tr>
<td>Beryl</td>
<td>Be$_2$Al$_2$(SiO$_3$)$_6$</td>
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<tr>
<td>Microcline</td>
<td>KAlSi$_3$O$_8$</td>
</tr>
<tr>
<td>Orthoclase</td>
<td>(Mg, Fe)$_2$SiO$_4$</td>
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<tr>
<td>Amber</td>
<td>C$<em>{10}$H$</em>{16}$O</td>
</tr>
<tr>
<td>Gold,</td>
<td>Au</td>
</tr>
<tr>
<td>Silver</td>
<td>Ag</td>
</tr>
<tr>
<td>Copper</td>
<td>Cu</td>
</tr>
<tr>
<td>Diamond and (Graphite)</td>
<td>C</td>
</tr>
</tbody>
</table>

Appendex 2: Questionnaire [English version]

Dear sir/madam

I am Hailemariam Mamo masters student of Medical Physiology at AAU conducting a research to determine the prevalence and types of cardio-respiratory problems and to assess the awareness and knowledge about the health effects of stone dust exposure among cobble stone workers in Addis Ababa.

I kindly request you to complete the following short questionnaire. It should take no longer than 10 minutes. Your response is of the utmost importance to me. Your participation is voluntarily. Your name remains anonymous and information you provide kept confidential.

Thank You in advance!

Part I: Personal information and work history

CODE No: ________.

1. Gender: Male… [ ] Female.… [ ] 2. Age: ________.


5. Had you ever had job before you join in this kind of work? YES… [ ] NO… [ ]

If you had been working in occupation that had dusts and chemicals, specify the kinds of dust or chemicals ____________________________________________________________________________.

6. How long you have been working here in the project? Encircle your response.

   A. 1-2 years  B. 2-3 years  C. 3 and above years

7. How long you stay working in the cobble stone work? Encircle your response in each options

   A. ≥ 8Hrs/day or < 8hrs/day  B. ≥ 7 Days/week or < 7 Days/week

   C. The whole year or ≤ 10 Months/year

8. Have you ever been visited your doctor as result of systemic illness related to your work?

   YES [ ] NO [ ]
9. If your response is NO for Q8 why you didn’t visit your doctor? Encircle your responses.

A. I didn’t have been injured  B. I didn’t bother for that injury C. I didn’t have money

B. Other reason______________________________________________________.

10. Had you or your natural father or mother ever told by a doctor that you or they had the following chronic lung or cardiovascular conditions? Tick the box where applicable.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Father</th>
<th>Mother</th>
<th>Neither</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Chronic bronchitis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Emphysema</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Asthma</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>D. Lung cancer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. Hypertension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F. Cardiac problems</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G. Other conditions</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Part II: Cardiorespiratory Symptoms and functional impairments

A. Acute symptoms

1. Have you ever experienced the following acute Cardiorespiratory Symptoms during working hour or the night following working days? (Tick your choice)

   I. Acute cough YES … NO…
   II. Shortness of breath YES … NO…
   III. Stuffy nose YES … NO…
   IV. Runny nose YES … NO…
   V. Sneezing YES … NO…
VI. Feeling of inhaling of the dust

B. Chronic Cardiorespiratory Symptoms. Tick your responses.

1. Do you usually cough first thing in the morning? YES… □ NO… □
2. Do you usually cough during the day or at night? YES… □ NO… □
3. If you say YES to Q4. Or Q5. Do you cough like this on most days for as much as three months each year? YES … □ NO… □
4. Do you have a cough for 3 months or more in total during a year? YES… □ NO… □
5. Do you bring up phlegm from your chest first thing in the morning? YES … □ NO… □
6. Do you usually bring up any phlegm from your chest during the day or at night? YES… □ NO… □
7. If you say YES to Q8 or Q9: Do you bring up phlegm like this on most days for as much as three months each year? YES … □ NO… □
8. Do you usually bring up phlegm (sputum) from your chest in the first thing in the morning? YES… □ NO… □
9. Do you usually bring up phlegm like this on most days for as much as three months each year? YES… □ NO… □
10. Do you have phlegm for 3 months or more in total during a year? YES… □ NO… □
11. Are you breathless or troubled by shortness of breath when you walk and ascend a hill at an ordinary pace? YES… □ NO… □
12. If you say Yes to Q15: Do you get shortness of breathing while you are walking with other people of your age on level ground? YES … □ NO … □
13. If you say Yes to Q16: Do you have to stop for breath when walking at your own pace on level ground? YES… □ NO… □
14. Have you ever had attacks of shortness of breath with wheezing? YES… □ NO… □
15. Is/ was your breathing absolutely normal between attacks? YES … □ NO… □
16. Do you wheeze in your chest? YES … □ NO… □
17. If you run, or climb MOUNTAINS fast do you ever
A. Cough? YES □ NO □  C. Get tight in the chest? YES □ O □

B. Wheeze? YES □ NO □

18. Is your sleep ever broken?
   A. By wheeze? YES □ NO □  B. By difficulty in breathing? YES □ O □

19. Do you ever wake up from your sleep in the morning with
   A. Wheeze? YES □ NO □  B. Difficulty with breathing? YES □ NO □

20. Do you ever wheeze when you are in a dusty condition/places? YES □ NO □

21. If you say YES to Q22, Q23, Q24, do the symptoms become decreased out of working hours or when you are out of dusty environment? YES □ NO □

22. Any other problem related to your lung or respiration______________________________.

23. Have you ever had any of the following cardiovascular or heart symptoms
   I. Frequent pain or tightness in your chest? YES …. □ NO … □
   II. Chest pain when you breathe deeply or during physical activity? YES □ NO … □
   III. In the past one or two years have you noticed heart skipping or missing a beat?
        YES… □ NO … □
   IV. Heart burn or indigestion that is not related to eating? YES … □ NO … □
   V. Any other problem related to heart or your circulation__________________________.

Part III: knowledge, attitude, practice (KAP) and awareness of cobblestone workers.

1. Should cobble stone workers wear protective and preventive devices (PPD)? YES… □ NO… □

   A. Always  B. Occasionally  C. Never
3. Type of devices you use during your work hours (You may have more than one response. Encircle your responses)
   
   A. Mask
   B. Respirator
   C. Glove
   D. Helmet/hat
   E. Coverall
   F. Apron
   G. Goggle
   H. Safety shoes
   I. Covering nostrils
   J. NEVER

4. Do you know that exposure to dust can affect your health negatively? YES… □ NO… □

5. If you say YES for Q4, Which one of the following could be health effect of stone dusts?
   You may have more than one response. Encircle your responses.
   
   A. Lung and airways problems
   B. Heart problem
   C. Skin diseases
   D. Eye problem
   
   List if you know any others

6. Do you have access to PPDs in your working area? YES … □ NO… □

   THANK YOU!
Appendix 3: Information for Consent request Form (English Version)

1. Study Subjects information: My name is Hailemariam Mamo. I am a post graduate student in department of Medical Physiology from School of Medicine, AAU. I am conducting a study on cardiorespiratory function among cobble stone workers in Addis Ababa. The study is sponsored by AAU, under supervision of Prof. Yoseph A. Mengesha. The Federal Labour and Social Affairs and Addis Ababa Cobble stone project coordination office have been giving administrative support and follow up.

The objectives of the study are:

✓ To determine the prevalence and types of cardiorespiratory problems associated with stone dust exposure among cobble stone workers in Addis Ababa.
✓ To assess acute and chronic effects of stone dust exposure on cardiopulmonary function.
✓ To evaluate the prevalence of cardiorespiratory symptoms arising from exposure to stone dust.
✓ To assess the awareness and knowledge of cobble stone workers about the health effect stone dust exposure and the possible effects on cardiorespiratory function.

2. Regarding the participation: If you agree to take part in the research work, you will be provided questionnaire so that you will fill it and examination of your cardiorespiratory function will be done. The examination involves cardiorespiratory function test by utilizing the Spirometry, Pulse Oximetry, Sphygmomanometer and Digital balance with meter.

3. Benefits: For all participants, health education and orientation on cardiorespiratory disease will be given throughout and at the end of the study. The participants could know their cardiorespiratory function status from the measurements. Participants who have severe cardiorespiratory symptom will be recommended to find further diagnosis and treatment. After the completion of the study, potential health risks of exposure to stone dust will be reported to Federal Ministry of Labour and Social Affairs and other concerned bodies so that prevention and intervention measures would be applied.

4. Risks: Responding private questionnaire and cardiorespiratory function test using the above equipments do not have any harm. May be, if you feel any discomfort, it is the participants full freedom to request for adjustment. You are requested to share your time at the early morning.
before work and when you get ready to home afternoon in the same day. The procedure will be administered in your working area based on your consensus so that it reduces time wastages for the procedures.

5. Confidentiality: Any information collected from you will be kept confidential. Your identity will not be disclosed in any situation. The information contained in the questionnaire and measurement will be kept confidential and the nature of the questionnaire is private. Code numbers will be used instead of your name for all the information. The results from physical examination will be identified by code numbers.

6. Study result disclosure: After analysis of the data, the investigator will present the result of the study to the responsible bodies. The report will not bear any information about you because code number will be used to disseminate the results to concerned bodies and for the purpose of publication.

7. Right to Refuse: Since your participation in the present study is entirely on voluntary basis, you may withdraw from the study at any time.

8. Right to get information: This study gets ethical clearance from departmental ethical committee of department of physiology and of faculty of Medicine, AAU. An agreement is signed with Ministry of Labour and Social Affairs. The participants could ask any questions for risk and discomfort (if any) that may result due to the procedures of the study.

If you have any question or concern during the study procedures, you can contact Hailemariam Mamo at any time using the following address

Hailemariam Mamo

Addis Ababa University

Faculty of Medicine, Department of Medical Physiology.

Tel: 0910634379

Email: hailemariammamo5@gmail.com

Addis Ababa, Ethiopia
Appendix 4: Consent Form

I, the undersigned, confirm that, as I give consent to participate in the present study, it is with a clear understanding of the objectives and conditions of the study and with recognition of my right to withdraw from the study if I do want not to participate.

I ___________________________ do hereby give consent to Mr. ___________________________ to include myself in the proposed research. I have been given the necessary information about the research. I have also been assured that I can withdraw my consent at any time without penalty or loss of benefits. The proposal is explained to me in the appropriate language I understand.

Name of the participant____________________

Signature ______________________

Date ______________________

Name of the Investigator____________________

Signature ______________________

Date ______________________