LUNG FUNCTION TESTS AMONG ARC WELDERS IN ZARIA, NORTHERN NIGERIA

BY

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DECLARATION

I declare that the research work in this thesis entitled: "LUNG FUNCTION TESTS AMONG ARC WELDERS IN ZARIA, NORTHERN NIGERIA" has been performed by me in the Department of Human Physiology under the supervision of Dr. Aliyu Mohammed and Dr.Yusuf Tanko. The use of works of other researchers was acknowledged and the source of information appropriately referenced. No part of the thesis was previously presented for another degree or diploma at any University.

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CERTIFICATION

This thesis, titled "**LUNG FUNCTION TESTS AMONG ARC WELDERS IN ZARIA, NORTHERN NIGERIA**" by Haruna Ozovehe SULEIMAN meets the regulation governing the award of degree Master of Science of Ahmadu Bello University, Zaria and is approved for its contribution to research and literacy presentation.

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DEDICATION

This work is dedicated to the Creator of the Universe, for showing me His mercy throughout the course of this programme; my beloved wife, children, parents; and members of Mal. Suleiman Ayinavoh's family, for their moral support.

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All praise be to Allah who has sustained and eased it for me up to this point in my educational pursuit.

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This warm appreciation goes to my wife, family members and friends for their support and encouragement towards the completion of this work. May Allah reward you all in abundance. AMIN.

ABSTRACT

The study of Lung functions among metal Arc welders in Zaria, Nigeria. Aim of the study was to evaluate long-term effects of exposure to welding fumes on lung functions. The metal Arc welders in Zaria study assessed 100 welders and 100 office workers by a questionnaire to record anthropometric data, work history and lung function status by spirometry. The average pulmonary function values of the welders were lower relative to controls. The mean forced vital capacity (FVC) of the welders was 2.95 ± 0.06 L, while that of the non-welders (control) was 4.03 ± 0.06 L; The mean forced expiratory volume in one second (FEV_1) for the welders was 2.38 ± 0.06 L and that for the control group was 3.36 ± 0.05 L ; The mean peak expiratory flow rate (PEFR) for the welders was 361.5 ± 5.82 L/min and that of the control group was 455.8 ± 5.96 L/min, All the values in welders were lower than those of the control ($P < 0.05$). The mean forced expiratory volume in one second percent (FEV_1%) for the welder was 81.48 ± 1.32 % while that of the control group was 84.22 ± 1.26 % ($P > 0.05$). Comparing the mean pulmonary variables of welders exposed for ≤ 5years and those exposed for ≥6years, the mean FVC and FEV_1% significantly decreased with years of exposure. The overall correlation matrix between years of exposure and pulmonary variables showed negative correlation in FEV_1 and FEV_1% and a significant difference in FEV_1%. The relationship between PEFR and FVC significantly increased as the years of exposure to the welding fumes increased. The results suggest that welders are at the risk of having an impaired pulmonary function.

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LIST OF ABBREVIATIONS

ABUTH	-	Ahmadu Bello University Teaching Hospital
BMI	-	Body mass index
COPD	-	Chronic obstructive pulmonary disease
DMT 1	-	Divalent metal transporter 1
FCAW	-	Flux core arc welding
FEV_1	-	Forced expiratory volume in 1 second
FVC	-	Forced vital capacity
GMAW	-	Gas metal arc welding
GTAW	-	Gas tungsten arc welding
IPF	-	Interstitial pulmonary fibrosis
MIG	-	Metal inert gas
Mn	-	Manganese
OA	-	Occupational asthma
PEFR	-	Peak expiratory flow rate
ROS	-	Reactive oxygen species
RSD	-	Residual standard deviation
SAW	-	Submerged Arc Welding

SMAW	-	Shielded Metal Arc Welding
UV	-	Ultraviolet radiation
WHO	-	World Health Organization

CHAPTER ONE

1.0 Introduction

Welding is a common industrial process where heat is applied to a specific area to join two or more metal parts (Antonini *et al.,* 2009).The adverse health effects of welding come from chemical and physical hazards. Common chemical hazards include metal particles, fumes and gases (carbon monoxide, nitrogen oxide and ozone). Physical hazards include electrical energy, heat, noise, vibration and radiation (Antonini *et al.,* 2003; Luo *et al*., 2006). Welders are exposed to inhalation of a number of fumes and gases (Jafari and Assari, 2004).Welding is a common and highly skilled occupational specialty. Welding processes involve inhalational exposures, which may lead to acute or chronic respiratory diseases. The primary source of inhaled particulate material in most welding processes is a consumable electrode of filler metal, which is partially vaporized. Metal fume is formed when vaporized metal condenses in air as metal oxide particles. These particles are very hazardous component of welding fumes for they are small enough to deposit in the terminal bronchioles and alveoli, distal to where mucociliary cleaning mechanisms takes place. These particles are known as the thoracic fractions which includes respirable fraction, and is defined as "the mass fraction that penetrates the respiratory system beyond the larynx" (Cherrie *et al*., 2010). Electric arc-welding processes produce particles with aerodynamic diameters, according to Jenkins and Eagar (2005), less than 10 – 30 % of fume mass is larger than 1 μm but it depends on the welding process used. These particles are predominantly composed of metals such as iron, nickel, molybdenum, manganese, chromium and their oxides (Antonini, 1998). Many respiratory problems are associated with welding, Lung irritation or injury may result from inhalation of submicron aerosols, causing pulmonary effects such as metal fume fever, cough, bronchitis, asthma, lung function decrements, increased susceptibility

to infection, pneumonitis, pneumonia and a possible increase in the incidence of lung cancer (Antonini *et al.*, 2003; Antonini *et al.*, 2006b; Liu *et al.*, 2008). Interstitial lung disease, (Erhabor *et al.*, 2001; Buerke *et al.*, 2002) asthma (Keskinen *et al.*, 2002*),* pneumoconiosis (Hull and Abraham, 2002).

Spirometry is an important tool for measuring the extent of impairment and assessing the response to treatment. When used in conjunction with the clinical and occupational history and chest radiographs, it helps to determine the nature and severity of lung disease (El-Zein *et al.*, 2003). During pre-employment evaluations, it can identify applicants with pre-existing respiratory impairment to assure proper job placement. Periodic re-testing of workers can detect pulmonary disease in its earliest stages, when corrective measures could be taken (McKay and Horvath, 1994).

1.1 Statement of the research problem

According to World Health Organization,(WHO) there are about 250 million cases of work-related injuries per year worldwide (WHO, 2002). One of the jobs that contribute to these occupational injuries is non-industrial welding, especially in developing countries, including Nigeria (Sabitu *et al.*, 2009). In metropolitan Kaduna, the former administrative capital of northern Nigeria, welders are usually located around mechanic workshops, motor spare-parts markets and along major highways, where they establish privately-owned, small-scale workshops. This group has no organized occupational health service and their adherence to safety measures is unknown (Sabitu *et al.*, 2009).

Welders cut and join metal parts using flame, electric arc or other sources of heat. There are three main classes of welding; namely, arc, oxyacetylene fuel and robotic welding. Some of the hazards of this occupation include ultraviolet (UV) and infrared radiation (IR) exposure, fumes

and particulate generation, thermal burns, occupational heat stress, exposure to electromagnetic fields, and electrocution (Lyttle, 2004). Similarly, the excessive lighting (glare) and exposure to UV radiation may lead to `arc eye' or `flash burn' injuries to the cornea, photokeratosis and double vision and consequent retinal damage. Welders are also exposed to noxious metal fumes which contain a variety of elements in its untainted forms which can be hazardous when inhaled or ingested by the worker (Jenkins and Eagar, 2005; Taube, 2012). These welding fumes can enter the lungs, bloodstream, brain nerve cells, spinal cord and other organs causing both short and long term health effects (Balkhyour and Goknil, 2010). Welding has been associated with various respiratory conditions. This may in turn, after chronic exposure, result in lung function impairment such as airway irritations, bronchitis and pulmonary function changes (Antonini *et al.*, 2003)

1.2 Justification of the study

Concerning the effects of welding fumes on lung function shows rather heterogeneous results (Antonini *et al.* 2003). Some studies found no difference between welders and controls, while others reported lower values of lung function parameters in welders (Jafari and Assari, 2004; Fidan, 2005), even after adjustment for smoking. Studies investigating an exposure–response of both welding intensity and welding duration (Ozdemir *et al.*, 1995) have reported discordant results.

Many researchers have evaluated the effects of welding fume inhalation on the lung function of welders, but there is disagreement among these studies. The majority of differences between findings in various studies are frequently due to bias from inclusion or exclusion criteria. The most important bias are smoking status of subjects, time-weighted average of exposure time like history of employment in years and day-time exposure in hours per day, type of welding

processes, existence and usage of protective measures (local or general ventilator, isolation of welding room in production site), and protective devices (Antonini *et al.,* 2003; Meo *et al.,* 2003). Ambiguous results have been observed in the literature and to the best of our knowledge, there are only few studies regarding respiratory effects of welders' exposure in Nigeria. So, the aim of present study was to evaluate the effects of welding fumes, and environmental pollutants on lung function.

1.3 Aim and objectives of the study

Aim

The aim of this study was to determine the effects of welding fumes on the pulmonary functions of metal Arc welders in Zaria, Northern Nigeria.

Specific objectives

The specific objectives of this study included:

1. To study the effects of welding fumes on forced vital capacity value (FVC) and to determine its severity in relation to duration of exposure to the fumes.
2. To determine the effects of welding fumes on the forced expiratory volume time (FEV_1) and to determine its severity in relation to duration of exposure.
3. To determine the peak expiratory flow rates of welders in Zaria, Northern Nigeria in relation to duration of exposure to welding fumes.

1.4 Hypothesis

There is a no relationship between long-term exposure to welding fumes and the pulmonary function parameters in welders.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Welding is a common industrial process where heat is applied to a specific area to join two or more metal parts. Melting of metals occurs as a result of heat, and after cooling the heat creates a strong connection between the metal parts. Throughout a welding process, small metal particles (or better known as welding fumes) and gases are released (Brown, 2012).Welding and cutting operations present certain potential hazards to welders that can result in temporary or permanent physical injury, short- or long-term adverse health effects, discomfort and even death. The potential health hazards associated with welding and allied processes include exposure to fumes and gases, heat, noise, radiation, and musculo-skeletal injuries (MSI's), such as strains and sprains. Therefore, welders are exposed to the inhalation of fumes and gases (Jafari and Assari, 2004).

2.2 Common Welding Processes and Fume Generation Rates

Welding fumes have a highly variable, complex composition consisting of particles and gases (Richman *et al*., 2011). The fumes consist of a variety of metal oxides including Manganese oxides. The fume composition, concentration of various metals, and solubility of each component as well as particle size distribution depends on the site-specific properties (temperature, moisture, and air exchange) as well as method-specific properties (the type of welding process used, welding consumables, voltage and the type of electrode or wire) (Taube, 2012).

2.2.1 Shielded Metal Arc Welding (SMAW, "stick welding") is commonly used for carbon steel welding and low alloy welding. In SMAW, the electrode is held manually, and the electric arc flows between the electrode and the base metal. The electrode is covered with a flux material, which provides a shielding gas for the weld to help minimize impurities. The electrode is consumed in the process, and the filler metal contributes to the weld. SMAW can produce high levels of metal fume and fluoride exposure; however, stick welding is considered to have little potential for generating ozone, nitric oxide and nitrogen dioxide (Antonini *et al.*, 2006).

2.2.2 Gas Metal Arc Welding (GMAW) or metal inert gas (MIG) welding is typically used for most types of metal and is faster than SMAW. This process involves the flow of an electric arc between the base metal and a continuously spool-fed consumable electrode. Shielding gas is supplied externally; hence, the electrode typically has no flux coating or core. Although GMAW requires a higher electrical current than SMAW, GMAW produces fewer fumes since the electrode has no fluxing agents. However, due to the intense current levels, GMAW produces significant levels of ozone and nitrogen oxides (Jenkins and Eager, 2005).

2.2.3 Flux Core Arc Welding (FCAW) is used for carbon steels, low alloy steels and stainless steels. This welding process has similarities to both SMAW and GMAW. The consumable electrode is continuously fed from a spool and an electric arc flows between the electrode and base metal. The electrode wire has a central core, containing fluxing agents, and additional shielding gas may be supplied externally. This welding process generates a substantial amount of fume due to the high electrical currents and the flux cored electrode. However, FCAW generates little ozone, nitric oxide and nitrogen dioxide (Brown, 2012).

2.2.4 Gas Tungsten Arc Welding (GTAW) is also known as tungsten inert gas (TIG) welding. GTAW is used on metals such as aluminum, magnesium, carbon steel, stainless steel, brass, silver and copper-nickel alloys. This technique uses a non-consumable tungsten electrode. The filler metal is fed manually and the shielding gas is supplied externally. High electrical currents are used, which causes this process to produce significant levels of ozone, nitric oxide and nitrogen dioxide (Antonini *et al.,* 2006).

2.2.5 Submerged Arc Welding (SAW) is another common welding process, used to weld thick plates of carbon steel and low alloy steels. In this welding process, the electric arc flows between the base metal and a consumable wire electrode; however, the arc is not visible because it is submerged under flux material. This flux material keeps the fumes down and since the arc is not visible, there is little ozone, nitric oxide and nitrogen dioxide that are generated. The major air borne hazard with SAW is the fluoride compounds, generated from the flux material (Antonini *et al.,* 2006).

2.3 Chemical analysis of welding fumes particles

2.3.1 Gases

All welding processes produce hazardous gases. Gases are invisible to the eye, and may not necessarily have an odour. The heat in both the flame and the arc, and the UV radiation from the arc, produces gases such as carbon monoxide, carbon dioxide, oxides of nitrogen and ozone. Other gases and vapours may be produced as by-products from the break-down of solvents or coatings on the metal. Gases used for arc shielding, or as a fuel, are also given off during welding (Brand *et al.,* 2012).

2.3.2 Welding fumes

The fume refers to the solid metal suspended in air which forms when vaporized metal condenses into very small particulates. The vaporized metal becomes oxidized when it comes in contact with oxygen in air. Therefore, the major components of the fume are oxides of metals, used in the manufacture of the consumable electrode wire fed into the weld. Some metal constituents of the fumes may pose more potential hazards than others, depending on their inherent toxicity (NIOSH, 2002). All welding processes produce these fumes, but most fumes are produced during arc welding. In this type of welding process, high heat from an electric arc (formed between the work and an electrode) is used to melt and fuse the metal at the joint between the two parts. When a welder strikes an arc, the arc's heat vaporizes a small quantity of metal and releases welding fumes into the air, which can adversely affect the health of the welder and other individuals in the immediate area (Jenkins and Eager, 2005).

2.4 Components of welding fumes

The contents of the welding fumes depend on the components of the base metal, coatings and/or filler materials and the temperatures used in the welding process. Melting of metals occurs as a result of heat, and after cooling the heat creates a strong connection between the metal parts. Throughout a welding process, small metal particles (or better known as welding fumes) and gases are released (Antonini, 2003). Types of metals commonly found in welding fumes include aluminum, beryllium, cadmium oxides, chromium, copper, fluorides, iron oxide, lead, manganese, molybdenum, nickel, vanadium and zinc oxides. Welding fumes also produce gases, which can contain carbon monoxide, fluorine, hydrogen fluoride, nitrogen oxide and ozone. In the welding fumes a complex array of metals, metal oxides and other chemical species volatilize from the welding electrode or the flux material incorporated within the electrode. Although it is

almost impossible to consume enough iron oxide to cause a toxic effect (Antonini, 1998), steels contain alloying elements that are in their pure forms could be hazardous to worker health, if inhaled or ingested (Jenkins and Eager, 2005).

All steels contain manganese, while stainless steels also contain chromium and nickel. Although essential for health in small doses, pure manganese is a neurotoxin that can cause manganese poisoning in large doses. Chromium and nickel can be carcinogenic. Welders are exposed to these elements, if they inhale welding fume. Welding fume consists of metal oxide particles that form during welding. These particles are small and remain air-borne and are easily inhaled. Chromium, nickel and manganese are not found as pure elements in welding fumes. They are present as impure compounds, which do not present the same toxic risk as pure elements. The oxidation state of chromium and manganese also affects their toxicity. Trivalent chromium is inert, whereas hexavalent chromium can be carcinogenic. There is evidence that the oxidation state of welding fume manganese is less toxic than that used to set manganese exposure limits Information regarding carcinogenicity in manganese exposed workers is very little, but results available do not indicate that inorganic manganese is carcinogenic, even though it causes mutations (Schonwald, 2004).

2.5 Health effects of welding fume exposure

Welding is the principal industrial process used for joining metals. However, it can produce dangerous fumes that may be hazardous to the welder's health. Presently, 1–2% of workers from different professional backgrounds (some 3 million persons) in the world are subjected to welding fume and gas action. In confined spaces, welding can be deadly, as without proper ventilation, toxic fumes and gases can be much more intense, and possibly over the respective limits for toxic substances (Pires *et al.*, 2007).

Worker exposure to welding fume is most often associated with acute and chronic lung damage, but there are a number of other health concerns. Although exposure to specific gases and metals are associated with certain disease outcomes (such as hexavalent chrome and lung cancer), health effects have also been well documented for total welding fume exposure (Brand *et al.*, 2012). Occupational exposure to welding may lead to adverse health effects in exposed workers due to chemical and physical hazards emitted as by-products. Chemical hazards include welding fumes and gases, whereas physical hazards include heat, noise, electrical energy, vibrations, and electromagnetic radiation. The fumes and gases generated during welding are considered to be the most harmful in comparison with other welding by-products (Antonini, 2003; Fidan *et al*., 2005).

Welding fumes and gases are produced at a sufficient rate to cause both short and long-term health effects, if not properly controlled. As Antonini, 2003 indicates, a large number of welders experience some type of respiratory illness, such as airway irritation, metal fume fever, bronchitis, chronic obstructive pulmonary disease, asthma, siderosis and other pulmonary fibrosis (chronic beryllium disease, cobalt lungs), lung function changes, an increase in severity, duration, and frequency of pulmonary infections, as well as a possible increase in the incidence of lung cancer. The exposure of welders to high concentrations of welding fumes in confined, poorly ventilated spaces also indicated large decrements in lung function in relation to welders working in well-ventilated areas (Antonini *et al*., 2003). The risk of developing lung cancer is narrowed to stainless steel welding, while mild steel welding, which accounts for 80 – 90 % of all welding in industries, and carries a low risk of lung cancer (Antonini *et al*., 2003). In addition, workplace exposure to welding fumes and gases may also lead to neurological, reproductive and dermal effects (Antonini, 2003; El-Zein *et al.,* 2003).

2.6 Pathogenesis

The formation of fume occurs due to the vaporisation of the metals. The volatilization takes place at the tip of the electrode, where the electric arc occurs. The electrode wire consumed during the welding process is the primary origin of the majority of the fumes. The formed welding fumes is the vaporized metal coming into contact with air causing oxidation to occur (Antonini *et al.*, 2003; Antonini *et al*., 2006a; Antonini *et al*., 2006b; Du Plessis *et al*., 2010; Antonini *et al*., 2011). This oxidation results in particle formation, primarily of respirable size, composed of a complex mixture of metal oxides (Harris *et al*., 2005; Lehnert *et al*., 2012; Pesch *et al*., 2012). The process, process variables, current level and composition of the wire/flux used during welding determine the type and quantity of the welding fumes produced. The larger the current levels are, the higher the fume rate becomes (Antonini *et al.*, 2003; Antonini *et al.*, 2011). Also depending on the welding process and the composition of the welding electrode, are the different oxidation states and different solubility properties Mn may occur in. The biological responses to Mn after inhaling welding fumes may be affected by these differences (Antonini *et al.*, 2003; Antonini *et al.*, 2006a; Antonini *et al.*, 2006b).

The agglomeration of particles may in addition be influenced by factors such as temperature, humidity and air motion (Lehnert *et al*., 2012). These particles, of which Mn is part of, can easily be absorbed into the blood subsequent to reaching the alveolar or pulmonary region of the respiratory tract after inhalation occured (Antonini *et al.*, 2006b; Dorman *et al.*, 2006).

The potential health impact associated with inhalation of welding fumes consisting of the appropriate metals innate to the welding process, depends on the site where the particles deposit in the respiratory tract, as well as how the particles will be cleared from the lungs (Antonini *et al.*, 2006b). The uptake of particles by the respiratory tract is chronological, causing particles to

move from the nasal/oral boundary through the respiratory system. The particles come into contact with the respiratory tract and move through the layers of the respiratory tract where it reaches the bloodstream or lymphatic system. Each layer, through which the particles move, provides a form of resistance to particle transport (Ferro and Hildemann, 2007; Pośniak and Skowroń, 2010).

The nasal-pharyngeal or extra-thoracic region, includes the nasal passages, the pharynx and the larynx. The function of this region is to warm and moisten the inhaled air and to filter out coarse particulate matter larger than 5 μm in the complex airflow patterns of its passages and these particles are known as the inhalable fraction (Antonini *et al.,* 2006b; Ferro and Hildemann, 2007; Pośniak and Skowroń, 2010). The second region, namely the trachea-bronchial or thoracic region, Particles in this region have an aerodynamic diameter of 2-5 μm and can easily access the bloodstream (Antonini *et al.,* 2006b; Ferro and Hildemann, 2007; Pośniak and Skowroń, 2010). These particles are known as the thoracic fractions which includes respirable fraction, and is defined as "the mass fraction that penetrates the respiratory system beyond the larynx" (Cherrie *et al*., 2010). The second region subdivides the airway to reach the third region, known as the alveolar, pulmonary or gas exchange region. The latter region, where gaseous exchange takes place, the alveoli are seen as tiny sacs which have an enormous surface area which facilitate gaseous exchange with the bloodstream. Particles with a diameter of less than 1 μm will be present in this region (Antonini *et al.,* 2006b; Ferro and Hildemann, 2007; Cherrie *et al*., 2010; Pośniak and Skowroń, 2010). These particles are known as the respirable fraction and are defined as "the mass fraction that penetrates to the unciliated airways of the lung, known as the alveolar region, where the gas exchange takes place" (Cherrie *et al*., 2010). Welding particles

with a diameter of 0.5 – 2.0 μm have been observed in a welder's breathing zone, increasing the probability of depositing into the lower respiratory tract (Antonini *et al.,* 2003; Antonini *et al.,* 2006b).

Welding particles, both soluble and non-soluble forms of metal which deposit in the nasal-pharyngeal region, can lead to direct transfer from the nose to the brain via olfactory transport, bypassing the first-pass hepatic clearance. While this transport occurs, another bypass at the blood-brain barrier may take place causing inhaled metals such as manganese, cadmium, nickel and mercury to be transmitted along cell processes to synaptic junctions with olfactory bulb neurons (Tjälve and Henriksson, 1999; Beuter *et al*., 2004; Dorman *et al*., 2004; Antonini *et al*., 2006b; Liu *et al*., 2008; Antonini *et al*., 2009). Mn is able to cross synapses within the olfactory pathway and it uses secondary and tertiary neurons to travel to other distal sites in the brain, including the hypothalamus (Tjälve *et al*., 1995; Dorman *et al*., 2006; Elder *et al*., 2006).

2.7 Acute health effects

Short-term exposures to welding fumes can cause shortness of breath, irritation to the eye, nose and throat, and other nonspecific effects such as headache and nausea. The effects are similar to those from exposures to just ozone and/or nitrogen dioxide, important components of welding fumes, but metal fume components also contribute to lung effects (Antonini *et al*., 2004).

Studies embarked upon in the past have also stated that inhalation of welding fumes may cause inflammatory lung diseases such as asthma (Pascal and Tessier, 2004). Fume exposure during occupational welding will result in an increase in metal concentration in biological fluids, causing an increase in systemic inflammation (Du Plessis *et al*., 2010).

Metal fume fever, defined in one study as "having at least two symptoms of fever, feelings of flu, general malaise, chills, dry cough, metallic taste, and shortness of breath, occurring at the beginning of the working week, 3-10 hours after exposure to welding fumes", may also be an indicator of welding-related asthma (El-Zein *et al.,* 2003). In addition to fluoride and aluminum, it is thought that chromium, nickel and/or molybdenum are some welding fume components that may contribute to asthma (Hannu *et al.,* 2007). There is some suggestion that manual metal arc welding may result in acute decreased lung function compared to other processes (Leonard *et al.,* 2010).

Generation of reactive oxygen species (ROS) is theorized as one mechanism for welding fume acute adverse health effects (Taylor *et al.,* 2003);with stainless steels, containing chrome and nickel producing more ROS than mild steel (Leonard *et al.,* 2010).

2.8 Chronic health effects

Primary concerns with chronic exposures include chronic bronchitis (a component of COPD), and lung cancer (Christensen *et al.,* 2008). Welding fume exposures have also been associated with: susceptibility to infections (Palmer *et al.,* 2009); decrease in semen quality and other adverse reproductive effects (welding-related heat and electromagnetic field exposures may also be contributors) (Meeker *et al.,* 2008).They are also associated with sino-nasal cancer (d'Errico *et al.,* 2009);sarcoid-like (immune response) lung disease (Kelleher *et al.,* 2000); peripheral artery disease, particularly cadmium (Navas-Acien, 2005); and cardiotoxicity (Fang *et al.,* 2010). A potential mechanism for cardiovascular disease and acute systemic inflammatory response, has been found in welding-exposed workers (Kim *et al.,* 2005). Siderosis, once thought to be an iron fume related "benign pneumoconiosis" without health effects, has been associated with pulmonary fibrosis (McCormick *et al.,* 2008).

2.9. Hazards on respiratory system

2.9.1 Chronic bronchitis: Chronic bronchitis is clinically defined as cough and sputum production, persisting for at least three months of the year for two consecutive years (Stulbarg and Zimmerman, 1996). Chronic bronchitis with air-flow obstruction is now the fourth leading cause of death among Americans. The trends over the past two decades indicate 60% increase in the mortality from chronic bronchitis (Wu and Center, 1997). Studies embarked upon in the past have also stated that inhalation of welding fumes may cause inflammatory lung diseases such as asthma (Pascal and Tessier, 2004). Fume exposure during occupational welding will result in an increase in metal concentration in biological fluids, causing an increase in systemic inflammation (Du Plessis *et al*., 2010). The exposure of welders to high concentrations of welding fumes in confined, poorly ventilated spaces also indicated large decrements in lung function in relation to welders working in well-ventilated areas (Antonini *et al*., 2003). The risk of developing lung cancer is narrowed to stainless steel welding, while mild steel welding, which accounts for 80 – 90 % of all welding in industries, carries a low risk of lung cancer (Antonini *et al*., 2003). Upper and lower respiratory tract infections shows a decrease regarding the incidence, severity and duration in welders in relation to the general population (Antonini *et al.*, 2003; Antonini *et al.*, 2011). An inflammatory response in the lung may occur due to inhalation of Mn -containing dust in certain occupational settings (Liu *et al*., 2008).The development of chronic bronchitis and other work-related respiratory symptoms in welders were related to exposure to a combination of dust and irritant gases in the work place. Many studies have noted an increased prevalence of cough and phlegm among welders. The shipyard welders and caulker/burners had a greater risk of chronic bronchitis. Among welders and caulker/burners who smoked, the increased risk of chronic bronchitis was related to the average fume exposure. Several previous studies have noted

that chronic bronchitis to be more prevalent in welders, however, this association has not been found in all studies (Bradshaw *et al.,* 1998).Erkinjuntti-Pekkanen *et al.,* (1999) reported that, chronic bronchitis was more common among welders (24%) than non-welders (5%). Erhabor *et al.,* (2001) reported that the most frequent symptoms found among welding workers were obstructive lung disease compared to controls.

2.9.2 Interstitial lung disease

Acute chemical pneumonitis caused by inhalation of zinc fumes (zinc oxide) was accompanied by chronic siderosis in welding workers. It is well known that metal fume fever commonly occurs in individuals, when inhaling zinc oxide fumes. However, acute chemical pneumonitis after exposure to zinc oxide during welding has been only rarely reported (Tojima *et al.,* 1998). Similarly, Buerke *et al.,* (2002) found interstitial pulmonary fibrosis (IPF) after long term, severe exposure to welding fumes in poorly ventilated workplaces. Erhabor *et al.,* (2001) reported that 40.9% of the subjects working in welding industry suffer from restrictive lung disease (interstitial lung disease).

2.9.3 Asthma

Occupational asthma (OA) can be defined as variable air-ways narrowing, casually related to exposure in the working environment to air-borne dusts, gases, vapors or fumes.

There are many agents in the work-place that can induce asthma or cause substantial deterioration in pre-existing asthma. It has been estimated that 5-15% of adult-onset asthma can be attributed to occupational exposures. Hence adult patients, especially those with new-onset asthma, must be investigated with regard to occupational risk factors for the disease. The prognosis for OA is improved if the causal exposure is controlled either by controlling the exposure at the work-place or by moving the patient out of the work-place. In a recent review of

studies largely carried out in developed countries, the American Thoracic Society estimated that approximately 15% of asthma was attributable to occupational exposure (Balmes *et al.,* 2003).

2.9.4 Chronic obstructive pulmonary disease

Chronic obstructive pulmonary disease is defined as a disease state characterized by progressive development of air-flow limitation that is not fully reversible. The air-flow limitation is usually both progressive and associated with an abnormal inflammatory response by the lungs to noxious particles or gases" (WHO, 2002). COPD overlaps with emphysema and chronic bronchitis, although some view the condition as a continuum of a single pathological process (Kirkhorn and Garry, 2000). Similarly, COPD is a different disease than the pneumoconioses, although clearly there is overlap between some of their pathological and clinical features (Becklake, 1994).

Chronic obstructive pulmonary disease was defined as occurring when the ratio of the forced expiratory volume divided by the forced vital capacity (FEV1/FVC) was less than 0.6, representing reasonably severe disease (Becklake, 1994).

2.9.5 Pneumoconiosis

The term pneumoconiosis is an occupational lung diseases caused by the caused by inhalation of dust and retention in the lungs. The word pneumoconiosis literally means dust in the lungs or dusty lungs. A more widely accepted definition is that "pneumoconiosis is the accumulation of dust in the lungs and the tissue reaction to its presence" (Abraham, 1992). Industrial welding has been associated with many respiratory problems, which vary from acute responses such as that seen in metal fume fever, to less common cases of hypersensitivity pneumonitis; and chronic sequelae, such as welding-related pneumoconiosis. Welders may also develop pneumoconiosis from tin oxide (stannosis), carbon dust (anthrocosis), and aluminum oxide (aluminosis).

Hull and Abraham (2002) showed that chronic exposure to high concentrations of fumes during aluminum arc welding causes a severe pneumoconiosis.

Tojima *et al.,* (1998) found that the respiratory health hazards associated with welding vary according to the materials and the concentration of inhaled substances. Welding workers suffer from acute chemical pneumonitis caused by inhalation of zinc fumes (zinc oxide) and accompanied by chronic siderosis.

2.10 Hazards on the Kidneys

Pesch *et al.* (2000) demonstrated that substantial exposure to metals and solvents may be nephrocarcinogenic, There is evidence for a gender-specific susceptibility of the kidneys.

2.11 Hazards on Eye

Tenkate (1998) reported that welding is one of the most intense artificial sources of optical radiation. Each type of welding process emits a different spectrum and intensity of optical radiation. For most processes, ultraviolet and visible radiations are the main components of the emission. Factors such as arc current, shielding gas and base metal influence the emission spectrum. Adverse effects are confined to the eyes, with welders suffering from a higher proportion of optical radiation associated eye conditions than do non-welders (Tenkate, 1998).

In addition, Tenkak (1999) reported that welding may cause photokeratitis and some types of cataract. Erhabor *et al.* (2001) reported that the most frequent symptoms found among the welders were eye irritation (95.43%). Okuno *et al.* (2001) reported that, arc welding emit high levels of UVR which often causes acute injuries in the work-place, particularly

photokeratoconjunctivitis. Guenel *et al.* (2001) showed the elevated risks of ocular melanoma for people with light eye colour, light skin colour, and for subjects with several eye burns.

A significantly increased risk of ocular melanoma also occurs in occupational groups, exposed to artificial UVR, but not in out-door occupational groups exposed to sunlight. An elevated risk of ocular melanoma was seen among welders (Odds ratio = 7.3; 95% confidence interval = 2.6-20.1 for men), and a dose-response relationship with job duration was observed (Guenel *et al.*, 2001).

2.12 Hazards on skin

Tenkate (1998) showed that erythema is a common skin condition among welders. Similarly, Tenkate (1999) also reported that, in the occupational environment, there are also many artificial sources, of which welding arcs are the predominant and most intense. Adverse health effects include erythema, pterygium, non-melanocytic skin cancer and malignant melanoma. Erhabor *et al.* (2001) observed 43.19% cases of skin irritation in arc-welders compared to the controls.

2.13 Hazards on reproductive system:

Tejral *et al.* (1993) conducted a study on the health state, as well as haematological, biochemical and cytogenetical changes of 53 stainless steel welders. Results were compared to those of non-exposed persons and to a group of firemen. Bonde (1990) conducted a cross sectional study concerning the male reproductive system in metalworkers and reported a moderate deterioration of semen quality in mild steel welders, but less reliable changes in semen quality were found in low exposed stainless steel welders. However, Bonde (1993) suggest that welding may not be detrimental to the male reproductive system. They investigated the semen quality and sex hormone concentrations among 17 manual metal arc alloyed steel welders with a

moderate exposure to radiant heat. The result showed that sperm count and motility were non-significantly reduced among welders in comparison with two different reference groups.

Wu *et al.* (1996) showed that the time from ejaculation to liquefaction of semen in exposed workers was longer than that in controls, and the volume of semen, sperm count, viable sperm count and percentage were significantly lower in the exposed workers than in the controls; Step-wise regression analysis suggests a direct toxic effect of manganese on sperm production. Gerber *et al*. (2002) stated that the fertility in mammals is affected by large quantities of Mn exposure causing embryo and foetus toxicity. Therefore pregnant woman should not be exposed to Mn at the workplace. Testicular dysfunction due to long term accumulation of Mn was also indicated in a study conducted by Ellingsen *et al*. (2007) although testicular pathology combined with impairment is unknown in Parkinson's disease patients. Taube (2012) stated that overexposure to inhaled Mn is a higher risk of developing infertility in the case of male workers. In accordance with Aschner *et al*. (2007) the conclusion can therefore be drawn that high dose exposure to Mn will cause an increase in tissue Mn levels which may result in adverse neurological, respiratory and reproductive effects.

2.14 Exposure and Biomonitoring

The welding industry emits an estimation of 5000 tons of welding fumes per year worldwide (Redding, 2002). Complex metal particles may occur in these fumes causing health effects after inhalation exposure (Antonini *et al*., 2011).Welders are exposed to aerosols, containing a mixture of elements and to gases such as ozone and nitrous oxides (Antonini, *et al.*, 2003). The aerosols are formed primarily through homogeneous nucleation of element vapour, followed by competing growth mechanisms such as coagulation and condensation (Zimmer, 2002).

Individual particles freshly formed near the welding arc are mainly spherical, with diameters ranging from 50 to 300 nm (Zimmer, 2002). The aerosol mass distributions are unimodal with geometric mean aerodynamic equivalent diameters from 0.29 to 0.59 mm (Hewett, 1995).Particle number measurements show that welding produces a log-normal particle mode with a 120 nm count median (Stephenson *et al.*, 2003). Thus, these respirable particles will easily penetrate more deeply into the lungs. The minimum alveolar deposition efficiency is around 25% for particles with a diameter of about 0.5 mm, with increasing deposition efficiencies at smaller particle diameters (Vincent, 1995).

The mechanisms of particle formation explain the tendency of particles to be formed with different chemical compositions from the core to the surface (Zimmer and Biswas, 2001). Bulk measurements suggest that Mn(II) and Mn(III) are the most probable oxidation states in welding fumes generated by manual or gas metal arc welding (Antonini *et al.*,2003). X-ray diffraction studies have identified a variety of Mn-containing compounds in welding fumes; for example,$KMnF_3$, MnO, K_2MnO_4, g-Mn_2O_3 and Mn_3O_4 (Voitkevich, 1995).

Pulmonary absorption of Mn in rats is higher for soluble than for less soluble compounds (Roels *et al.,* 1997). This may also be the case in workers producing Mn alloys (Ellingsen *et al.,* 2003). Little is known about the solubility of Mn-containing welding fume particles in the lungs, but the solubility increases according to the increasing content of fluorine and potassium in the welding fume (Voitkevich, 1995). The understanding of the pulmonary uptake mechanisms of welding fume components is insufficient. Transferrin receptors and divalent metal transporter 1 (DMT 1) that are found on the surface of the lung epithelial cells may point to a role of these transporters in mediating the uptake of divalent and trivalent cations (Turi *et al.,* 2004).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

Vitalograph machine, Wright peak flowmeter, stadiometer, cotton wool, and methylated spirit,

3.2 Ethical consideration

The approval of the ethical committee (ABUTH/HREC/E23/2013) for the protection of human subjects was obtained from Ahmadu Bello University Teaching Hospital, Zaria was obtained Informed written and signed consent, consistent with the ethical committee recommendation above were obtained from all subjects.

3.3 Demography of study area

Zaria is a heterogeneous city in Kaduna state, inhabited by 1, 490,000 people (Akpa *et al.*,2002). It located in the Sudan savannah climatic zone which is located on 11º11! N and 07º38! E. The rainfall in this region is less than 1000 mm per annum in only about five months in the year, especially between May and October. Rainfall in this zone is highly variable and the onset of the rain is erratic. The rainfall intensity is very high between the months of July and August, the period of Harmattan is a transition period between the Wet and the Hot Seasons. It is a period when there is little or no rainfall (Ati, 2002). Daytime temperature may drop to 31ºC, giving a variation of 17ºC, and the highest in the year. This extreme diurnal temperature range is another characteristic of the Savanna type of climate (Areola *et al.*, 2006).

3.4 Experimental design

This research was designed to measure the pulmonary function variables. Variables measured were: forced vital capacity (FVC), forced expiratory volume timed and as well forced expiratory volume in second percent (FEV_1/FVC) and the expiratory flow peak expiratory flow rate (PEFR). The standing height and weight of the welders and the control group were also measured.

3.5 Setting

The research was done in the laboratory of the Department of Human Physiology Ahmadu Bello University, Zaria. Parameters of the pulmonary functions were measured in the arc welders, recruited from different metallic construction workshops in Zaria. The welders (Study group) were asked to assemble at a particular station close to their workshops for easy accessibility, the spirometry machine was transported down, and tests were conducted with the assistance of a laboratory technician. Each participant was enlightened about the dangers of welding fumes and pulmonary function tests, and measurements of anthropometric parameters were taken from each subject. Those found to have pulmonary function defect were asked to perform further lung function investigations, since spirometry was not a final diagnostic test to show lung defects.

3.6 Subject selection/exclusion criteria

A total of 200 adult males of ages between 20-50 years were selected using simple random sampling method from different areas in Zaria. The choice of the sample size of 200 subjects was due to previous research of Sayed *et al.,* 2011. One hundred metal arc welders were used (study group). One hundred non-welders comprising of staffs and students who are not exposed to welding fumes were also used as controls. The selection included the different ethnic groups within the Northern part of Nigeria.

Exclusion criteria

i. Smokers were excluded from the tes0ts.

ii. Subject with any known respiratory impairment, disease or symptoms were also excluded from the study.

iii. Subject with recent chest surgery and cardiopulmonary diseases were also excluded.

iv. Subjects less than 20 years old were excluded from the test.

The sample size (n) was calculated according to Araoye (2003) using the formular below:

$$n' = \frac{2z^2pq}{d^2}$$

n= desired sample size

z= standard normal deviate i.e. confidence limit 95% (z=1.96) was chosen.

p=proportion of welders

q=proportion of non-welders

d= degree of accuracy desired, usually set at 0.05

Adapted from Araoye (2003) to calculate sample size

3.7 Basic information and history taking

Basic information was obtained about the subject through a questionnaire. Important information that was gathered on the subjects included the following:

A. Basic information, subject name, age, standing height (metres) and weight (kg) were measured, and body mass index (kg/m^2) was calculated.

B. Personal medical history/screening ; medical history included whether the subject ever had allergies; for example hay fever, asthma, chest injury or surgery, recurring colds, pneumonia/Recurrent lung infection, lung abscess, tuberculosis, hypertension, lung

cancer, pulmonary fibrosis, bronchiectasis, emphysema or chronic bronchitis (Madama,1998).

3.8 Methods

Pre-test procedures/instructions

Subjects were asked about smoking, recent illness and medication use.

Subjects were told not to involve themselves in any form of strenuous exercise. Subjects were told not to wear any restrictive clothing (necktie, buttoned shirt collar, tight belt) at the time of the test, any restrictive clothing worn was loose.

3.8.1 Test procedures (forced vital capacity and forced expiratory volume timed (FEV_T)

Test procedures were carried out following the recommendations of American Thoracic Society (Miller *et al.,* 2005). Pulmonary function tests were performed with a vitalograph machine at a fixed time (8:00-11 hours) of the day to minimize diurnal variation.(Glindmeyer *et al.,* 1994).

The weight and height without shoes were measured. The Instructions and demonstration of the test to the subject were performed, for easy understanding of the test procedures.

They instructions included: Correct posture with head slightly elevated, Inhaling rapidly and completely, position of the mouthpiece (open circuit) exhaling with maximal force.

Test instructions:

The subjects were asked to take the deepest breath they could, and then exhale into the sensor as hard as possible, for as long as possible, preferably at least 6 seconds. Maneuvers were performed in a standing position without a nose clip and disposable mouthpieces were used for each individual. The highest lung function value was chosen out of three attempts, irrespective of the test and as recommended by the American Thoracic Society (Miller *et al.,*2005).

PREDICTIVE EQUATIONS

FEV1 $1.08 \cdot (4.30 \cdot \text{height} - 0.029 \cdot \text{age} - 2.49)$ L RSD = 0.51

FVC $1.10 \cdot (5.76 \cdot \text{height} - 0.026 \cdot \text{age} - 4.34)$ L RSD = 0.61

FEV1%FVC $87.2 - 0.18 \cdot \text{age}$ RSD = 7.17

Standing height in metre, age in year (Brändli *et al*.,1996).

The RSD is the residual standard deviation, i.e. standard deviation about the predicted values after allowing for age and height. Substitute 25 yr in the equations for any adult under 25 year (Brändli *et al*.,1996).

3.8.2 Peak expiratory flow rate

The PEFR is dependent on effort and lung volume, with subject cooperation being essential. PEF must be achieved as rapidly as possible and at as high a lung volume as possible, in order to obtain the maximum value (Pedersen *et al.,* 1997). Following the recommendations of American Thoracic Society (2013), a clean mouthpiece was connected, ensuring that the marker was set to zero.

Test instructions

Subject was asked to stand up or sit upright, take a deep breath and hold it. The mouthpiece was placed in mouth of the subject and forms a tight seal as possible around it with his lips. The subjects were encouraged to blow as vigorously as possible. The neck was in a neutral position, not flexed or extended, and the subject did not cough, this was observed and the reading was recorded. The process was repeated 3-4 times and the highest reading was recorded as recommended by the American Thoracic Society (2013).

3.9 Statistical analysis

Statistical analysis was conducted using unpaired T-test to compare mean values between the two groups. Pearson's correlation analysis was used to establish the relationships between the variables. Data were analysed using SPSS version 20.0 software (IBM, New York, USA). The data generated were expressed as mean ± standard error of the mean(mean ± SEM). P-value less than 0.05 was considered significant.

CHAPTER FOUR

4.0 Results

Table 4.1: Anthropometric characteristics of control group and welders (n = 100)

	Mean ± SEM	
	Controls	**Welders**
Age (years)	25.04 ± 0.23	27.12 ± 0.73
Weight (kg)	65.81 ± 0.94	64.27 ± 1.06
Height (m)	1.71 ± 0.007	1.6 ± 0.01
BMI (kg/m^2)	22.69 ± 0.37	22.29 ± 0.31

BMI= Body Mass Index

Table 4.1 shows the anthropometric characteristics of control group (non-welders) and arc welders who took part in the study. They non-welders were age-matched students and staff of the University, who were not exposed to welding fumes and did not smoke.

The mean age was 25.04 ± 0.23 years, weight 65.81 ± 0.94 kg, height 1.71 ± 0.007 m and body mass index was(BMI) 22.69 ± 0.37 kg/m^2. The values obtained for the arc welders were as follows: Age 27.12±0.73years, Height 1.69±0.01m, and Weight 64.27±1.06, Body mass index (BMI) 22.29±0.31 kg/m^2.

Table 4.2: Pulmonary parameters of control groups and welders (n = 100)

Parameters	**Mean ± SEM**	
	Control	**Welders**
FVC(L)	4.03 ± 0.05	2.95 ± 0.06 *
FEV_1(L)	3.36 ± 0.05	2.38 ± 0.06*
FEV_1/ FVC (%)	84.22 ± 1.26	81.48 ± 1.31*
PEFR(L/min)	455.8 ± 5.96	361.5 ± 5.82*

FVC = Forced vital Capacity; FEV_1 = Forced expiratory volume in 1 second;

PEFR = Peak expiratory flow rate, * Denotes significant difference ($P < 0.05$)

Table 4.2 shows the pulmonary variables of the control group (non-welders) and welders who took part in the study. The controls were age-matched students and staff of the University, who were not exposed to welding fumes, who did not smoke or have any history of cardio-pulmonary disease. The mean value of the different variables are as follows: FVC, 4.03 ± 0.05 l; $FEV_{1,}$ 3.36 ± 0.05 l; FEV_1/FVC, 84.22 ± 1.26 % and PEFR was 455.8 ± 5.96 l/min, for the welders the mean value of the different parameter determined were FVC, 2.95 ± 0.06 l, $FEV_{1,}$ 2.38 ± 0.06 l, FEV_1/FVC, 81.48 ± 1.31 %; and PEFR, 361.5 ± 5.82 l/min with statistical difference ($P < 0.05$) in all the parameters.

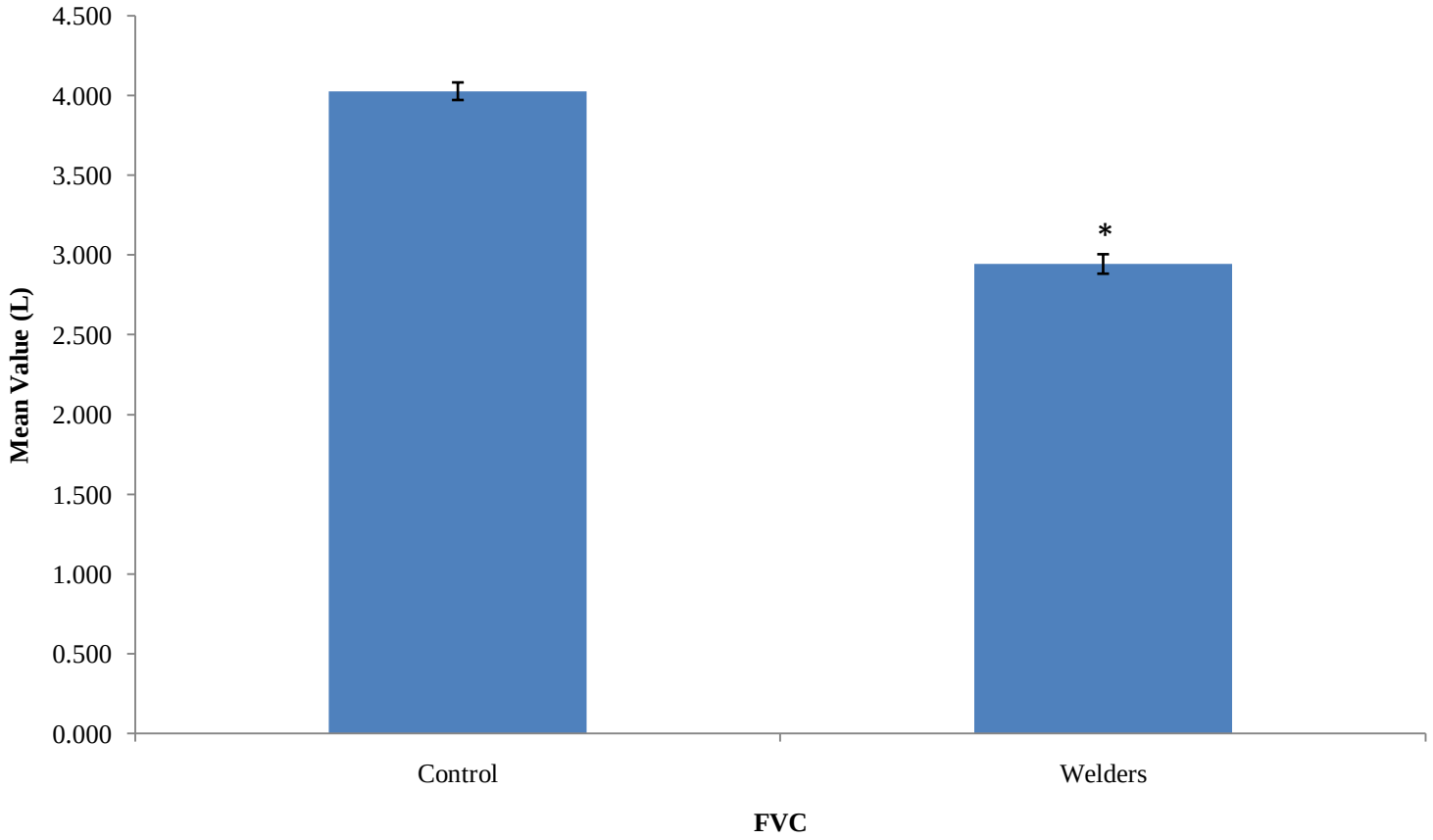


Fig.4. 1: Forced vital capacity (FVC) of welders and non-welders, n =100

***denotes significant difference p < 0.05**

As shown in Figure 4.1 above, FVC of the arc welders was 2.95 ± 0.06 l, while that of the non-welders (control) was 4.03 ± 0.06 l this showed a statistical difference of $P < 0.05$.

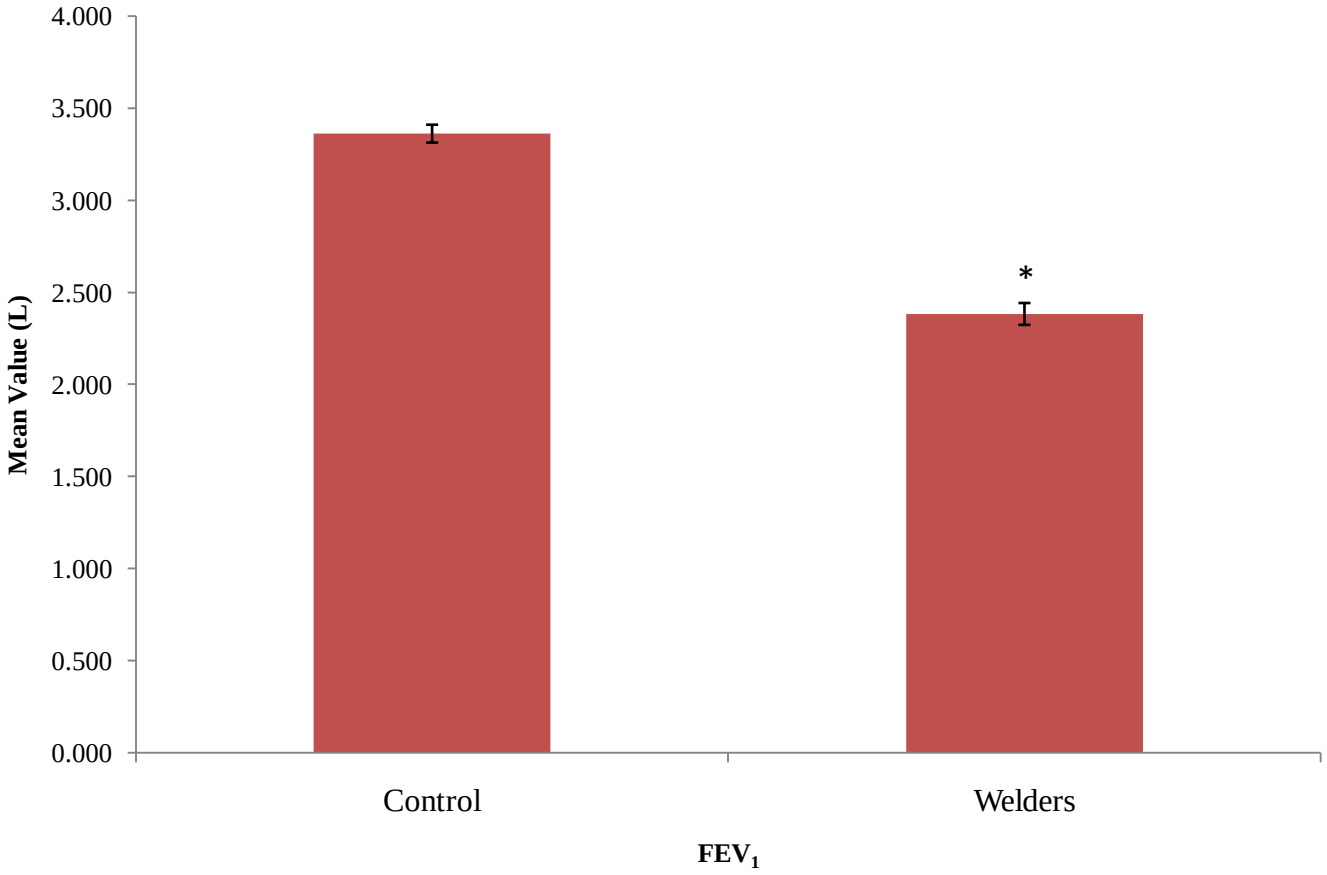


Fig. 4.2: Forced expiratory volume in 1 second (FEV_1) of welders and non-welders

***Denotes significant difference $p < 0.05$, n =100**

The mean forced expiratory volume in one second (FEV_1) for the control group was 3.36 ± 0.05 l, the arc welders was lower 2.38 ± 0.06 l ($P < 0.05$), (fig.4.2).

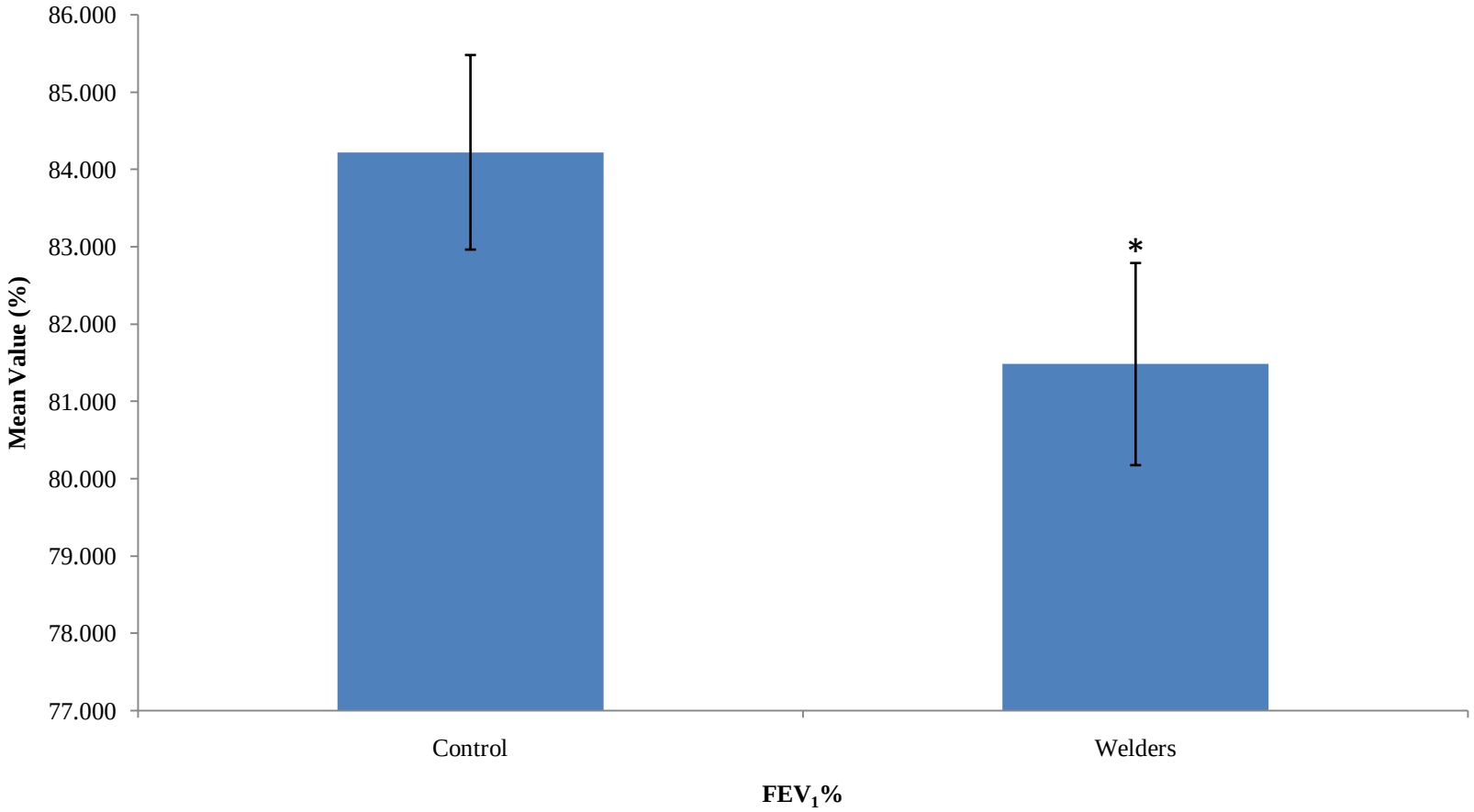


Fig.4.3: Forced expiratory volume in 1 second percent (FEV1%) of welders and non-welders, n =100

* denotes **significant difference P <0.05**

The forced expiratory volume in one second percent (FEV_1%) for the control group was 84.22 ± 1.26 % and that of the arc welders was 81.48 ± 1.32 %, the values showed significant ($P < 0.05$) difference(fig.4.3).

*

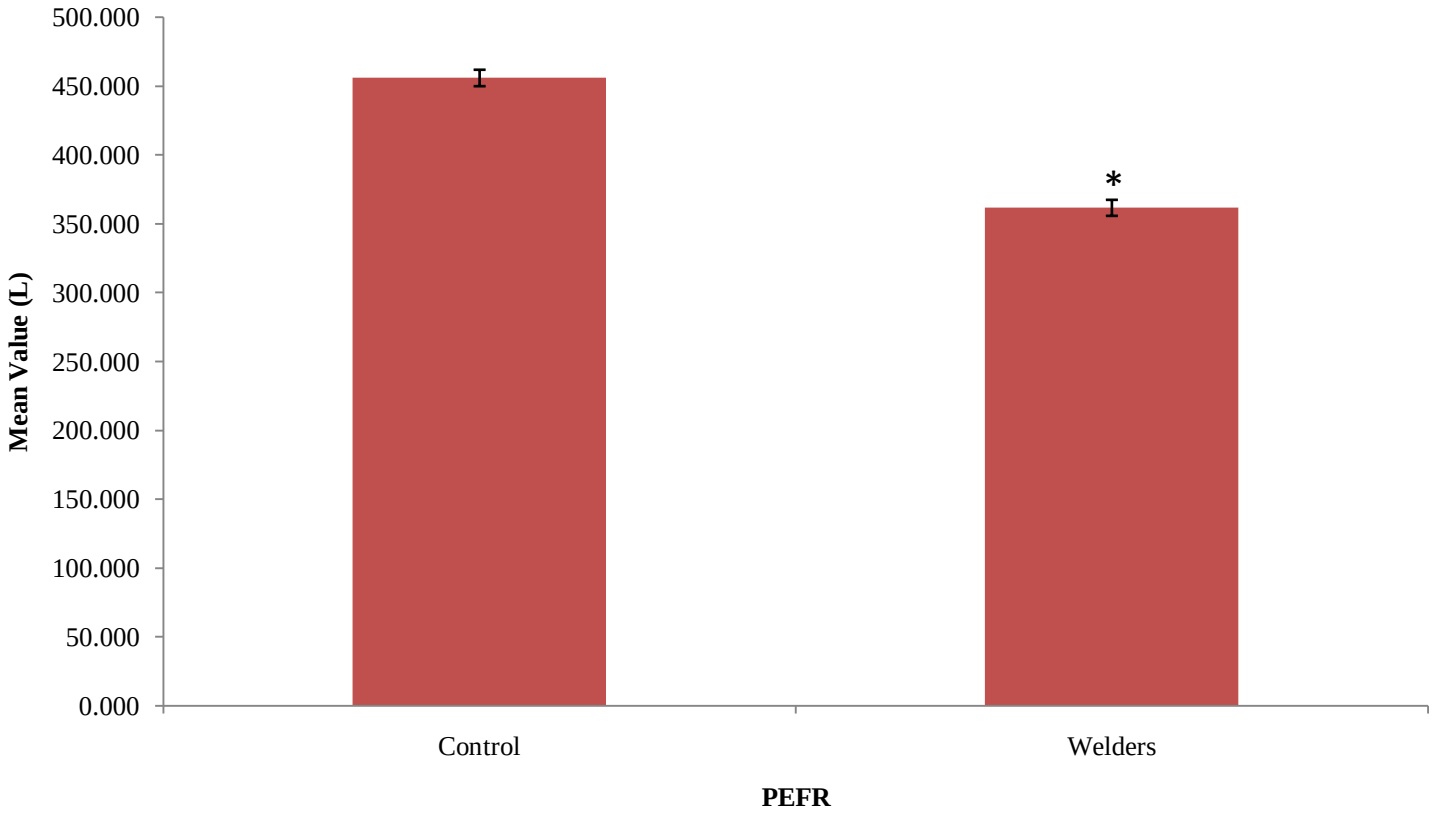


Fig. 4.4: Peak expiratory flow rate (PEFR) of welders and non-welders.*denotes significant difference p < 0.05

The PEFR for the control group was 455.8 ± 5.96 l/min greater ($P < 0.05$) than that of the arc welders is 361.5 ± 5.82 l/min (fig.4.4).

Table 4.3: Comparative evaluation of Pulmonary parameters based on years of exposure to welding fumes

Pulmonary parameters	**Exposure ≤ 5 Years (n = 46)**	**Exposure ≥ 6 Years (n = 54)**	**P-value**
FVC (l)	3.10±0.08	2.76±0.09	0.004*
FEV_1 (l)	2.35±0.09	2.41±0.08	NS
FEV_1 %	84.91±1.84	78.56±1.76	0.014*
PEFR (l/min)	363.89±8.16	358.70±8.33	NS

FVC, Forced vital Capacity; FEV_1, Forced expiratory volume in 1 second;

PEFR, Peak expiratory flow rate, *denotes significant difference $P < 0.05$

NS = $P > 0.05$

Table 4.3 shows the relationship between the years of exposure and the pulmonary function variables, the mean FVC for arc-welders with exposure ≤ 5 years was 3.10 ± 0.08 l, and the value for those exposured ≥ 6 years was 2.76 ± 0.09 l ($P < 0.05$). FEV_1 for arc-welders with exposure ≤ 5 years and ≥ 6 years were 2.35 ± 0.09 l and 2.41 ± 0.08 l, respectively. The difference in the values was not significant. FEV_1% for arc-welders with exposure ≤ 5 years and ≥ 6 years were 84.91 ± 1.84 % and 78.56 ± 1.76 %, respectively ($P < 0.05$). The PEFR for the arc welders with exposure ≤ 5 years and ≥ 6 years were 363.89 ± 8.16 l/min and 358.70 ± 8.33 l/min respectively ($P > 0.05$).

Table 4.4: Correlation matrix showing the relationship between years of exposure of arc-welders and pulmonary parameters.

Pulmonary parameter	r	P-value
FVC(l)	0.092	S
FEV_1(l)	-0.015	NS
FEV_1/ FVC (%)	-0.101	S
PEFR(l/min)	0.149	S

FVC, Forced vital Capacity; FEV_1, Forced expiratory volume in 1 second;

PEFR, Peak expiratory flow rate, S =P < 0.05; NS =P > 0.05.

Tables 4.4 shows the correlation between years of exposure of arc-welders and pulmonary parameters. The FVC regression value was 0.092 in relation to the years of exposure and showed a significant difference between the variables ($P < 0.05$). FEV_1 regression value was -0.015 in relation to the years of exposure ($P > 0.05$) between the variables, although there was negative relationship between years of exposure and FEV_1.

FEV_1/FVC (%) regression value was -0.101 in relation to the years of exposure and there was a significant difference between the variables ($P < 0.05$), though there was a negative relationship between them i.e. years of exposure and FEV_1/FVC (%). This proved that duration of exposure to welding fumes has a negative effect on this pulmonary variable. PEFR showed regression value of 0.149 in relation to the years of exposure ($P < 0.05$) significant between the variables though there was a positive correlation.

CHAPTER FIVE

5.0 DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Discussion

The assessment of pulmonary function with a spirometer has become common practice in patient settings and industry. There are many respiratory problems that may be associated with welding. They include metal fume fever (most frequent acute respiratory complaint), asthma, chronic bronchitis, increased frequency and severity of respiratory tract infections, pneumoconiosis (uncommon), potential risk for lung cancer and alteration of lung function tests (Sjogren, 1994; Antonini, 2003).

The biological effects of exposure to welding fumes have generated much interest and numerous studies have been carried out in welders. The results of previous epidemiological studies have not been consistent (Ozdemir *et al*., 1995). These surveys are difficult to compare because of differences in study populations, industrial settings, welding techniques and duration of exposures other occupational exposures, besides welding fumes and gases, as well as of the kinds of protective measures taken (Antonini, 2003). The type of welding process, what the electrode is made of, base metals and filler metals, as well as paints and other coatings on the metals being welded are considered as the major determinants of the risk for adverse respiratory effects associated with welding (Antonini,2003; Lyttle, 2004).

.The result of the present study revealed that welding causes changes in respiratory system and affects respiratory volumes, capacities and lung functions. Additionally these changes depend on the length of the contact with the particles. Welding is accompanied with side-effects caused by welding fumes.

In the present study, the FVC, FEV_1, FEV_1% and the PEFR in Arc welding workers showed a significant decrease as compared to their matched control group. The result of the present study is consistent with the findings of previous investigators, and further confirmed that welding exposure adversely affects pulmonary function (Ozdemir *et al.*,1995; Bradshaw *et al.*,1998; Erhabour, 2001; El-Zein *et al.*,2003; Jafari and Asari, 2004; Luo *et.al.*, 2006; Azian *et al*.,2014). The results were in accordance with the study of Wolf *et al.* (1997) on welders. Meo *et al.* (2003) also showed decrease of lung function in Pakistani welders in comparison to those of the control group. Similar result was obtained in Luo *et al.* (2009) on the welders of a car-manufacturing factory. Bhumika *et al.* (2012) studied the welders in a ship-building factory and reported decrease of lung functional tests. Previous studies reported decrease of lung functional tests and changes in chest X-ray in welders (Li *et al.,* 2004; Kakooei *et al.,* 2012). Komeili *et al.* (2013) in their comparative study of lung functional tests in Zahedan welders also reported decreased lung function in welders.

The result of the present study also showed that welders with exposures $\geq$ 6years, when compared with welders having $\leq$ 5years of exposure showed a decreased trend in FVC and FEV_1% and PEFR with a significant difference in FVC and FEV_1%. This shows that there was decrease in the lung function with increase in years of exposure. This finding was consistent with the finding of Sobaszek *et al.,* (2000) who showed significant decrease in lung function with increase in years of exposure to the welding fumes.

The relationship between welding exposure duration and decreased pulmonary function were in agreement with other findings (Luo *et al.*,2006; Azian *et al*., 2014).

Seyed et *al*. (2011) also reported welders with exposures longer than five years showed a significant reduction in FEV_1, FEV_1/FVC and $FEF_{25-75\%,}$ relative to low-exposure welders.

Stoleski *et al.* (2012) found lower values of spirometric parameters in welders with duration of work-place exposure more than 12 years than in welders, occupationally exposed less than 12 years with significant difference for MEF_{50}, MEF_{75}, and MEF_{25-75}. In a study about the effects of welding fumes on lung function in non-smoking Pakistani welders, who worked without the benefit of welding fume control ventilation and respiratory protective devices. Meo *et al.* (2003) reported significant reduction of FEV_1, FEV_1/FVC and PEFR with an effect of years of welding on lung function. Azian *et al.* (2014) also reported pulmonary function status among welders in Malaysian's automotive industries. Welders with exposure of than 10 years of working duration, and showed the same trends of decrease mean value of FVC and FEV_1 parameters in more than 10 years working welders.

The present study also showed that there was a significant negative correlation between the pulmonary function variables, FEV_1 and FEV_1/ FVC and the years of exposure, which agreed with the findings of many researchers (Rastogi *et al*. 1991; Sobaszek *et al*., 2000; Meo, 2003; Azian *et al*.,(2014). Seyed *et al.* (2011) reported that welding exposure was significantly associated with decreased $FEF_{25-75\%,}$ and that work duration was significantly associated with decreased FEV_1, FEV_1/FVC and $FEF_{25-75\%}$.

The decrease of the lung functional tests result had a reverse relation with welding history. This reverse relation between occupational background and lung functional tests was also reported in the study done by Bhumika *et al.*, 2012. This was possibly due to continuous inhalation of these welding fumes over a long period of time in the work place.

5.2 Conclusion

The present study was carried out to examine the pulmonary function of metal arc welders in Zaria, The welders recruited for the study used any form of metal available for their constructions. Most of the welders who participated in the study usually carried out their welding activities in open spaces available in their workshops, only a few work in confined environment with respiratory protectors/guards. From the results obtained, welding in open environment has a mild effect on the extent of lowering the pulmonary function due to exposure to the fumes, but long-term exposure to may be detrimental to the lungs of the welders. Therefore, welders who weld in confined environment, smoke and do not use any respiratory protective device are at risk of chronic obstructive lung disease.

5.3 Recommendations

The following recommendations are pertinent on the welders and also considerations for further research:

1. Welders should imbibe the habit of using respiratory protection gadgets to protect them from welding fumes, dust, allergens and aerosols and must get pre-employment and periodic medical surveillance.
2. Welding activities should be performed in open space that is well-ventilated environment to prevent incidence of chronic obstructive lung disease at the long run, and use local-exhaust ventilation to remove fumes and gases at their sources in still air.
3. Welders should use the safest welding materials and remove all the paint and solvents before welding or torch cutting and make sure all residues are removed.

4. Our study was limited by the fact that radiological examination and other measures of lung function for example, diffusing capacity, total lung capacity and blood gases were not examined, so further studies should be conducted to measure these parameters.
5. Further study should be performed involving large sample size using other sophisticated modern devices to assess lung function.
6. Our study brings to the focus the increasing hazard that workers in developing countries encounter on a daily basis. There is need to educate the workers on the hazard and for government to introduce means of monitoring possible toxic products at the worksite and enforcing safety measures.

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APPENDIX I

RAW DATA SHOWING ANTHROPOMETRIC AND PULMONARY VARIABLES FOR WELDERS

S/n	Age (yrs)	Height (m)	Weight(kg)	BMI(kg/m^2)	FVC(L)	FEV_1(L)	FEV 1%	PEFR(L/min)	Exposures(yrs)
1.	35	1.7	77	26.64	2.8	2.7	96.42	470	19
2.	20	1.74	60	19.87	2.4	2.2	91.67	370	5
3.	25	1.77	61	19.49	2.6	2.1	80.74	350	2
4.	28	1.65	61	22.42	3.3	3.1	93.94	410	2
5.	30	1.69	64	22.38	2.5	1.5	60	400	7
6.	48	1.64	69	25.65	2.85	2.7	94.74	360	20
7.	34	1.62	56	21.37	2.4	2.3	95.83	330	5
8.	21	1.67	57	20.43	3.7	3.5	95.8	400	5
9.	26	1.75	63	20.59	2.8	2.5	89.29	440	2
10.	20	1.7	60	20.76	3	2.8	93.33	390	3
11.	20	1.62	51	19.47	2.2	2.1	95.45	370	3
12.	22	1.65	61	22.43	2.8	2.5	89.29	360	5
13.	30	1.7	66	22.84	3.2	2.8	87.5	330	14
14.	20	1.63	56	21.05	1.5	1	66.67	320	3
15.	19	1.6	52	20.31	2.45	2.4	97.96	260	4
16.	30	1.8	70	21.6	3.7	2.8	75.68	380	9
17.	33	1.74	85	28.05	3.45	2.65	76.81	330	20
18.	35	1.67	63	22.58	2.3	2.2	95.65	330	4
19.	21	1.62	53	20.23	3	2.8	93.33	330	9
20.	20	1.68	60	21.28	2.5	2.4	96	370	4
21.	22	1.68	57	20.21	3.3	3	90.9	380	4
22.	23	1.58	48	19.2	2.7	2.6	96.3	340	3
23.	20	1.58	55	22	2.95	2.6	87.83	350	2
24.	25	1.59	57	22.53	1.7	1.1	64.7	310	5
25.	28	1.68	75	26.5	3.5	2.6	74.29	400	15

26.	22	1.65	50	18.38	3.65	3.4	93.15	450	4
27.	21	1.7	61	21.11	3.3	2.6	78.79	450	9
29.	20	1.7	54	18.69	3.25	3.1	95.38	360	3
30.	20	1.61	54	20.85	3.3	2.95	89.39	410	3
31.	20	1.72	53	17.91	2.8	2.7	96.42	340	2
32.	20	1.65	45	16.54	2.6	2	76.92	300	3
33.	20	1.71	57	19.52	2.55	2.4	94.12	400	3
34.	21	1.77	67	21.41	2.6	1.75	67.3	300	7
35.	25	1.64	55	20.45	3.8	1.8	47.37	350	3
36.	30	1.66	60	21.73	3.2	1.6	50	280	14
37.	22	1.76	64	20.65	3.25	2.2	67.69	370	3
38.	25	1.75	60	19.6	3	2.5	83.33	300	4
39.	23	1.62	54	20.53	2.7	2.3	85.19	340	3
40.	40	1.65	70	25.74	3.2	2	62.5	390	25
41.	22	1.74	78	25.74	3.6	3.3	91.67	350	8
42.	32	1.72	68	22.97	4.5	3.5	77.78	350	12
43.	25	1.63	60	22.56	2.5	2	80	330	4
44.	24	1.72	64	21.62	3.1	3	96.77	400	15
45.	22	1.77	69	22.04	2.6	2.2	84.62	500	4
46.	27	1.68	60	21.28	2.3	2.2	95.65	400	13
47.	30	1.74	72	23.76	2.2	2	90.91	370	18
48.	29	1.72	90	30.41	1.8	1.3	72.2	410	4
49.	32	1.7	70	24.22	4.4	3.6	81.82	450	9
50.	30	1.62	70	26.72	2.5	1.9	76	350	15
51.	23	1.63	60	22.47	2.5	2.3	92	300	3
52.	26	1.67	64	22.93	3.5	1.5	42.85	330	6
53.	39	1.7	80	27.68	2.8	2.6	92.86	400	20
54.	32	1.7	55	19.03	3.5	2.6	74.29	390	15
55.	23	1.63	58	22.39	3.4	3	88.23	300	4
56.	20	1.7	61	21.11	2.5	2.1	84	360	2
57.	50	1.82	104	31.42	3	2.2	74.33	300	36

58.	30	1.78	83	26.18	2.5	1.3	52	350	15
59.	30	1.73	79	18.93	3.1	2.1	90.41	440	14
60.	23	1.73	67	22.41	3.5	2.8	80	350	4
61.	31	1.7	80	27.68	3.3	2.55	77.27	380	13
62.	32	1.7	47	16.26	3.2	3	93.75	380	16
63.	30	1.71	59	20.21	2.1	1.8	85.71	270	20
64.	23	1.73	70	23.41	3.7	3.3	89.19	550	5
65.	29	1.72	58	19.59	3.4	2.7	79.41	360	10
66.	45	1.67	71	25.4	2.6	2.5	96.15	450	30
67.	33	1.78	63	19.87	3.8	1.7	44.73	430	15
68.	25	1.55	55	22.92	2.2	1.7	77.27	320	10
69.	27	1.71	60	20.55	3.7	2.9	78.38	380	15
70.	50	1.76	75	24.19	2.5	2.3	92	450	4
71.	25	1.72	77	26.1	2.5	1.5	60	300	5
72.	20	1.62	51	17.47	3.4	2.85	83.82	340	7
73.	24	1.65	60	22.6	2	1.8	90	350	5
74.	28	1.85	65	19.1	3.2	2.8	87.5	280	14
75.	25	1.73	70	23.41	4	2.7	67.5	350	7
76.	20	1.62	59	22.52	2.8	2	71.43	300	7
77.	28	1.85	65	19	3.5	2.3	65.71	280	15
78.	20	1.74	64	21.19	3.5	2.9	82.86	400	8
79.	21	1.72	60	20.27	1.8	1.5	83.33	300	3
80.	45	1.75	73	23.86	2.1	1.8	85.71	500	29
81.	38	1.72	73	24.66	2.4	1.7	70.83	430	20
82.	22	1.62	60	22.9	2.3	1.9	82.61	340	6
83.	20	1.62	53	20.23	2.3	1.2	52.17	380	3
84.	21	1.63	63	23.68	2.4	1.6	66.67	350	4
85.	30	1.75	60	19.6	3	2.3	76.67	360	7
86.	23	1.78	70	22.08	2.4	1.8	75	300	8
87.	30	1.75	80	26.12	3.3	2.4	72.73	330	12
88.	30	1.7	64	22.15	3.8	3.7	97.37	350	5

89.	25	1.67	62	22.23	3.35	2.45	73.13	280	10
90.	35	1.55	69	28.72	2.2	1.9	86.36	250	10
91.	30	1.66	84	30.48	3.15	2.2	69.84	380	10
92.	25	1.7	59	20.42	3.7	3.2	86.49	300	5
93.	27	1.73	70	23.39	3.3	3.2	96.97	300	6
94.	30	1.7	70	24.22	3.8	3.5	92.11	510	11
95.	49	1.77	70	22.36	3.4	2.4	70.59	300	2
96.	22	1.7	66	22.84	2.6	2.2	84.61	350	10
97.	35	1.8	102	31.48	3.7	2.8	75.68	350	20
98.	20	1.63	50	18.8	2.3	2.1	91.3	320	4
99.	20	1.71	52	17.81	2.2	2.1	95.45	300	2
100.	24	1.73	60	20.06	3.0	2.2	74.33	280	7

APPENDIX II

RAW DATA SHOWING ANTHROPOMETRIC AND PULMONARY VARIABLES FOR THE NON- WELDERS (CONTROL GROUP)

S/no.	Age (yrs)	Height (m)	Weight(kg)	BMI(kg/m^2)	FVC(L)	FEV 1(L)	FEV 1%	PEFR(L/min)
1.	25	1.77	76	24.35	5.4	3.6	66.67	460
2.	22	1.73	65	21.82	3.7	2.9	78.38	410
3.	29	1.75	60	19.42	3.4	3.25	95	430
4.	29	1.73	62	20.58	3.75	3	80	530
5.	23	1.8	58	17.87	4.2	3.25	77.38	490
6.	23	1.68	61	21.68	3.55	3.1	87.32	490
7.	23	1.69	64	22.44	4.3	3.08	71.63	650
8.	26	1.8	67	20.66	3.9	3.43	87.95	410
9.	26	1.65	61	22.4	3.65	3.28	89.86	440
10.	24	1.82	58	17.42	4.08	3.23	79.17	430
11.	26	1.71	75	25.65	3.85	3.1	80.52	430
12.	22	1.75	67	21.88	3.95	3.35	84.81	490
13.	26	1.84	94	27.85	4.68	2.9	61.97	460
14.	23	1.77	60	19.25	3	2.4	80	440
15.	24	1.68	52	18.5	2.9	2.65	91.38	450
16.	24	1.64	68	25.54	3	2.9	96.67	420
17.	26	1.72	52	17.58	3.65	3	82.19	440
18.	27	1.77	72	22.98	3.6	2.55	74.34	510
19.	22	1.79	54	16.92	3.7	2.1	58.33	440
20.	27	1.74	71	33.45	4.2	3.1	83.78	410
21.	26	1.76	73	23.63	5.35	3.4	80.95	400
22.	27	1.8	71	20.1	3.6	4.13	77.2	450
23.	27	1.6	51	19.8	4	2.75	76.39	390
24.	30	1.6	62	22.2	4.45	3.04	76	440

25.	27	1.83	68	20.16	3.55	4.05	91.01	460
26.	25	1.67	63	22.41	3.65	3.2	90.14	510
27.	27	1.65	67	24.76	3.6	3.35	91.78	490
28.	24	1.6	53	20.7	4.1	3.1	91.47	370
29.	22	1.64	61	22.68	4	3.1	58.78	370
30.	20	1.76	62	19.53	3.63	3.6	83.46	550
31.	28	1.66	50	20.02	3.9	3.4	80.57	360
32.	21	1.63	64	22.31	4.3	2.9	77.09	420
33.	25	1.65	65	21.41	5	3.55	68.69	450
34.	27	1.75	69	22.53	4.45	3.5	78.65	340
35.	24	1.75	77	25.14	3.65	3.6	98.63	410
36.	26	1.7	62	21.45	3.35	3.15	94.03	350
37.	23	1.7	72	24.91	3.8	3.5	92.11	460
38.	24	1.71	75	25.65	4.8	4.4	91.67	600
39.	26	1.55	52	21.64	4.1	2.4	58.53	380
40.	21	1.7	65	22.49	4	3.6	90	400
41.	26	1.76	61	19.69	4.5	3.75	83.33	380
42.	24	1.74	73	24.11	4.55	3.8	83.52	490
43.	24	1.69	69	24.16	3.95	3.6	91.14	510
44.	27	1.73	70	23.39	4.55	4.05	89.01	550
45.	22	1.7	51	17.65	3.9	3.3	84.62	450
46.	23	1.9	73	20.22	4.5	4	88.89	510
47.	23	1.7	70	24.22	4.05	3.8	93.83	350
48.	24	1.68	63	32.32	3.9	3.6	92.31	520
49.	23	1.71	51	17.44	4	2.9	72.5	400
50.	23	1.7	59	20.42	3.1	2.15	69.35	350
51.	22	1.64	49	18.22	3.1	2.3	74.19	440
52.	24	1.75	67	21.88	4.35	3.75	86.21	520
53.	27	1.74	71	23.45	3.9	3.4	87.18	410
54.	27	1.76	73	23.45	4.6	3.8	82.61	420
55.	26	1.82	57	17.42	4.55	3.5	76.92	560

56.	30	1.6	62	24.22	4.45	3.45	77.53	450
57.	23	1.76	66	31.31	4.35	3.15	72.41	500
58.	25	1.7	65	22.6	3.85	3.3	85.71	420
59.	23	1.69	64	22.44	4.75	3.45	72.63	440
60.	25	1.77	76	24.35	6	3.95	65.83	460
61.	23	1.73	61	17.87	4.2	3.8	71.43	550
62.	23	1.77	60	19.25	3.35	2.65	79.1	460
63.	25	1.74	74	24.44	3.5	3.15	90	340
64.	24	1.64	68	25.54	3.25	3.15	96.92	400
65.	27	1.6	50	19.8	3.95	3.3	83.54	400
66.	29	1.75	59	19.43	3.7	3.5	94.59	440
67.	29	1.74	57	18.83	4.4	3.4	77.27	430
68.	25	1.74	58	19.19	4.6	3.85	83.7	410
69.	26	1.8	67	20.66	4.25	3.8	88.37	410
70.	27	1.65	61	22.4	4.2	3.65	86.9	450
71.	27	1.77	51	16.85	3.8	2.9	76.32	490
72.	22	1.83	67	20.16	3.65	2.3	63.01	510
73.	27	1.84	94	27.85	4.9	4.5	91.83	570
74.	26	1.8	71	22.1	4.75	3.3	69.47	460
75.	27	1.71	75	25.65	5.5	4.5	81.81	470
76.	26	1.72	52	17.58	4.2	3.5	83.33	470
77.	25	1.67	67	22.11	4	3.5	87.5	420
78.	25	1.68	52	18.5	3.95	2.8	70.87	490
79.	24	1.69	80	27.9	4	3	75	460
80.	23	1.68	68	24.11	4.7	3.6	76.6	470
81.	28	1.58	77	30.8	3.8	3.8	100	520
82.	25	1.66	82	29.71	4	3.6	90	500
83.	26	1.65	68	25	3.9	3.8	97.44	550
84.	24	1.78	68	21.45	4.2	4	95.23	530
85.	29	1.77	76	24.28	4.4	3.4	77.27	460
86.	24	1.66	92	33.33	4	3.65	91.25	570

87.	28	1.7	92	31.83	4.2	3.5	83.33	460
88.	22	1.69	72	25.17	3.9	4	100	540
89.	24	1.78	65	20.5	4.3	3.4	79.07	470
90.	26	1.78	62	19.56	3.8	3.6	94.73	460
91.	26	1.7	65	22.49	4	3.8	95	470
92.	27	1.69	63	22.03	3.8	3.5	92.11	500
93.	20	1.57	76	30.89	3.8	3.5	92.11	450
94.	20	1.67	65	23.3	3.9	3.8	97.43	420
95.	29	1.67	74	26.52	4	3.8	95	450
96.	25	1.7	70	24.22	3.5	3.2	91.42	470
97.	28	1.6	59	23.05	4.2	3.25	77.38	390
98.	26	1.65	67	24.76	4.15	3.4	81.73	470
99.	29	1.74	57	18.83	4.4	3.4	77.27	420
100	27	1.77	72	22.98	3.6	2.55	74.34	380

APPENDIX III

CONSENT FORM

I……having fully understood the experimental protocols and procedures for the research, accept your request to volunteer as a subject for the research titled; **Lung functions tests among metal arc welders in Zaria, Kaduna state, Northern Nigeria.** To be conducted by SULEIMAN, Haruna Ozovehe of the Department of Human Physiology, Faculty of Medicine, Ahmadu Bello University, Zaria

Signature ……

Address …….

Phone number ……..

APPENDIX IV

QUESTIONNAIRE

I am a postgraduate student of the Department of Human Physiology, Faculty of Medicine, Ahmadu Bello University Zaria. I am conducting a research on the **Lung Function Tests among metal arc Welders in Zaria, Kaduna state, Northern Nigeria.** I wish to request for your participation as a subject for this research.

N.B. Information provided in this questionnaire shall be strictly kept confidential. Hence your maximum cooperation and sincerity is required while filling it.

IDENNTIFICATION NO: …….

DATE: DAY MONTH YEAR

TIME OF THE DAY 24hrs HOUR MINUTE

Basic information

Name……

Sex……

Age……

Standing height (meters) …….....

Weight (kg)…….....

Body mass index (kg/m^2)…….....

Personal Medical History

1. In the last 6 weeks, have you had major surgery or been hospitalized for a heart attack? Yes □ No □
2. Have you ever undergone major abdominal or chest surgery? Yes □ No □
3. Have you ever being diagnosed of any injury or abnormality of the vertebral column or thoracic cage? Yes □ No □
4. Have you ever been diagnosed of diabetes mellitus or any cardiopulmonary disease? □ Yes □ No
5. Are you under a doctor's care for high blood pressure? □ Yes □ No
6. Have you suffered from any allergy recently e.g. Hay fever, recurrent colds □ Yes □ No

7.Have you used an inhaled bronchodilator; i.e. Mist, Ventolin, etc., within the last 6 hours?□ Yes □ No

9.Which of these diseases have you suffered from indicate if any? (a) Asthma (b) Pneumonia/recurrent lung infection (c) Lung abscess (d) Tuberculosis (e)

Hypertension (F) Lung cancer (g)Pulmonary fibrosis (h)bronchiatasis(i) emphysema or chronic bronchitis

10.Do you smoke cigarette or chew tobacco? (Yes or No)

11. If yes, for how long? (a) more than 3years (b) 5-8 years (c) more than 9 years

12. Have you eaten a full meal within the last hour? If yes, wait one hour before testing. □ Yes □ No

13. Have you had any caffeinated beverages within the last 6 hours? □ Yes □ No

14. Are you wearing any tight or restrictive clothing? □ Yes □ No

Occupational exposures for welders

- How many years have you spent in the welding job?

(a) Less than 2 years (b) 3- 8years (c) more than 9 years.

- How many hours do you spend in your work shop every day?

(a) Less than 3hours (b) average of 6hours (c) 9-12hours

- Do use any protective respiratory device when in the work shop? (Yes or No)
- How many days of the week do you come to the work shop? (a) 3days (b) less than 3days (c)5 -7days

Pulmonary Function measurements

- Forced vital capacity (FVC)……
- Forced Expiratory Volume Timed (FEV_T)

(a) FEV_1……

(b) FEV_2.....

(c) FEV_3……

Forced Expiratory Volume 1% (FEV_1%)……..

Peak Expiratory Flow Rate (PEFR)……..

APPENDIX V

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Chief Medical Director: DR. LAWAL KHALID, *MBBS, FMCS, FWACS, FRCS(ED) mni*
Chairman, Medical Advisory Committee: DR. ABDULLAHI MOHAMMED, *MBBS, FWACP FICS*
Director of Administration: BARR. ISHAK BELLO, *LL.B, BL, LL.M, PGDM, AHAN, FCAI*

Our Ref: ABUTH/HREC/TRG /36 28th June, 2013

FULL ETHICAL CLEARANCE AFTER COMMITTEE REVIEW