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THE EFFECT OF SOLDERING FUMES ON LUNG FUNCTION IN CALABAR MUNICIPALITY

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SUMMARY
The objectives of this study were to evaluate the long term (6 months) effect of soldering gases and fumes on lung function and the prevalence of respiratory symptoms among solderers in Calabar Municipality, Cross River State. A comparative study using questionnaires and spirometry in ten (10) male electronics repairers engaged in rosin-based soldering of metallic joints in technical workshops and ten (10) male medical students and staff as control was performed. Two groups with similarity in age, height and weight were used. The mean age (25–54) years for the technicians was 34 ± 0.09 years; while that of students and some staff of medical school (25-54) years was 37 ± 1.56 years; The technicians were constantly exposed to the poisonous gas (3-4) hours daily, while the staff and students who were not exposed to the fumes served as control group. Measurements were made of their forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) during the course of a working shift, using a Vitallograph-Compact portable spirometer. The mean duration of exposed workers to solder fumes was (15 ± 1.62) hours. The prevalence of respiratory symptoms (eye irritation, running nose, wheezing, fatigue and mild cough) amongst the technicians was (72% versus 48%). This was significantly higher ($p<0.05$) as compared with the unexposed control group. There was a decrease ($p<0.05$) in mean peak expiratory forced rate (PEFR). Also, the means in forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), and percentage of forced expiratory volume in one second ($FEV_1\%$) were observed to be significantly reduced ($p<0.05$) respectively among the electricians. From the results obtained, no significant decrease was observed in control subjects of medical school. In conclusion, the study has shown a slight change in lung capacity and volume amongst solder-lead workers. Although the change in lung function is relatively insignificant, it hardly posed any appreciable decrease in physical activity and capability of the technicians.

KEYWORDS: Soldering fumes, lung function, respiratory symptoms, Calabar Municipality.

INTRODUCTION

Soldering is a process in which two or more items are joined together by melting and putting a filler metal into the joint, the filler metal having a lower melting point than the adjoining metal. Unlike welding, soldering does not involve melting the work pieces. In the past, nearly all solders contained lead, but environmental and health concerns have increasingly dictated use of lead-free alloys for electronics and plumbing purposes (Courtney, 1985; Lee *et al.* 1994; Brady, 1997; Palmer and Crane, 1997; Mark, 2007 and White, 2018). Unfortunately, most technicians are exposed to lead when repairing or building equipments using lead based solder.

Lead poisoning is an environmental and public health hazard of global dimension (Serpil, 2006; Geoff, 2015; Mahipal *et al.*, 2016; WHO, 2018). Children and adults in virtually every region of the world are being exposed to unsafe levels of lead in the environment (Chisolm and Harrison 1956; Patrick, 2006 and Rubin and Strayer, 2008). It can be from a single high level exposure or the cumulative effect of repeated high or low level exposures (Sitting, 1985 and Needleman, 1990). Exposures to lead are of various sources; from paints, food, water, air, etc. (Sitting, 1985; OSHA, 1989). In 1985, Courtney had reported that significant health problems could arise from simply breathing in solder smoke. According to (Ferris, 1978; Gupta *et al*. 1991 and Palmer and Crane, 1997), scientific data inundates the cumulative effects that lead has on the body, central nervous system, and the formation of red blood cells.

Although today, the problems with lead are no longer in doubt. The questions about lead's effect on the environment and those who come in contact with it have been around nearly as long as lead itself. Unfortunately, many solder workers are yet to come to terms with this reality, damning the health consequences in pursuit of making ends meet. According to Pierce (2005).

Measurement of pulmonary function tests provide a guide to the state and function of the respiratory system of an individual. It is useful in distinguishing a healthy respiratory system from a diseased or damaged one.

It is on this premise that this research sets out to evaluate and bring to fore the effect of soldering gases and fumes on lung function and respiratory symptoms among solderers in technical workshops in Calabar Municipality.

This report is confined to respiratory effects in men exposed to solder fumes.

MATERIALS AND METHODS

The study was conducted in various work stations located within Calabar Municipality. Twenty (20) male subjects were used for this study, amongst who were ten (10) technicians exposed to rosin-based solder fumes for a period of three months. Ten (10) subjects from Medical School who do not smoke, and were not exposed to lead solder fumes. Care was taken such that, subjects who had previous history of pulmonary diseases were excluded from participating in the study. Ethical Consent was obtained from the Ethical Unit of the Faculty.

Questionnaire

A simplified version of standardized questionnaire as approved by the Medical Research Council on Respiratory symptoms and used by (Cotes, 1987) was issued to all subjects. The questionnaire was designed to ascertain the subject's personal data and medical fitness such as: the state of health, history of respiratory disorders (asthma, cough, chest discomfort, tuberculosis, bronchitis) drinking and smoking habits and the presence of symptoms during occupational session. It also included data such as age, height, weight, sex, and nationality as well as duration of exposure to solder-lead fumes and as such, each subject completed the questionnaire first before proceeding with the pulmonary function test.

Subjects Used

An inclusion and exclusion criterion was done using the method of Johannessen *et al*. (2007). The subjects were carefully instructed before carrying out the test. Their understanding was tested twice before the final reading was taken. In achieving this, the maximal inspiration and expiratory volume was done fully and forcefully into the spirometer.

Measurement of Peak Expiratory Flow Rate (PEFR)

The measurement of peak expiratory flow rate was done using the method as described by Daniel (2018). A mini Wright peak flow meter (Armed, Clarke International Ltd) was used to detect the lung volume and capacity; measure the peak expiratory flow rate in l/min of the participating subjects. This measures the rate of flow of exhaled air at the start of the forced expiration. To ensure accurate measurement, the subject was made to sit upright, inspire maximally and with a dipped nose, expires fully and forcefully into the spirometer with great speed through the mouthpiece which was sterilized by methylated spirit after each use. Three buttons which are red, yellow and green in color were used to determine the result of each expiration, the middle button was controlled after the third time in one minute interval, and the best of the value was taken as the peak expiratory flow rate.

Lung volume and capacity

Measurement of lung volume and capacity was made using a Vitalograph-Compact Portable Spirometer calibrated for volume on a twice daily basis. Procedures were performed in accordance with the American Thoracic Society Standards for spirometric measurements (Ferris, 1978). Four Parameters of lung function were measured: forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1). Subjects were seen during the course of a working shift. Assessments were conducted over a similar period of the working day at each company site, and individuals were processed in an order that was independent of prior assessment of exposure. The results were compared with the group unexposed to solder fumes as defined by Quanjer (1983).

Weighing balance

The bathroom Scale was used for this study. Subjects were instructed to remove their shoes and heavy objects in their pocket before measuring their weight. Measurement was taken while the subject was standing upright on the weighing balance.

Measurement of height

A stadiometer was used for measuring the height of subjects. It is constructed out of a ruler, and a sliding horizontal headpiece adjusted to rest on top of the head. Measurement was taken while the subject was standing upright on the stadiometer.

Vitalograph readings

Measurement technique was carried out using the method described by Hosie & Nimmo, 1988). At the start of the test, the subject was instructed to inspire as deeply as possible, holding his nose and exhale forcefully through a mouth-piece connected to the vitalograph. The power source of the machine was turned on at the start of the measurement; the motor was triggered automatically as each subject exhaled. The recording chart was moved horizontally and the hyperbola was recorded. The height of the tracing was read off from the vertical marked for Ambient Temperature (20^0C). Barometric pressure (760mmHg) was saturated with water vapor. The scale was calibrated from 0 – 8 (L/s).

Precautions

The technicians resumed work every day between the hours of 8 am, and dismiss at 5 pm daily throughout the duration of the experiment. The test was carefully conducted in 5 hours after a period of exposure to the solder fumes. A questionnaire was filled by each subject. Subjects were carefully instructed before tests were conducted. Their understanding of material instructions was tested twice before results were taken.

While conducting the spirometry test, the subjects' knowledge and understanding of the vitalograph were brought to bear. Records of their lung functionality were displayed on the chart fixed to the machine. Readings which were obviously inaccurate due to faulty technique or lack of an airtight seal were ignored and the measurement repeated. The mouth piece was sterilized after every use by the subject. The tests were performed while subjects were in standing posture.

Statistical Analysis

Results were given in mean ± standard error of the mean (SEM). All statistical analyses were performed using the student t-test with SSPS 13 computer software. P< 0.05 was considered statistically significant.

RESULTS

Weights

The mean weight for the male technicians was 69.39 ± 0.47 kg in test group. The mean weight for the control group was 70.83 ± 0.89 kg. There was no significant difference in mean body weight between the control and the test group (Table 1).

Heights

The mean height for subjects in the test group was 1.69 ± 0.09 meters. The mean height for subjects in the control was 1.69 ± 0.01 meters. There was no significant difference in mean height values between the control and test group (Table 1).

Respiratory symptoms

The prevalence of respiratory symptoms (eye irritation, running nose, wheezing, fatigue and mild cough) amongst the technicians was (72% versus 48%). This was significantly higher (p<0.05) when compared with the unexposed control group (Table 1).

Table 1: Mean Values for Body Weight, Height And Respiratory Symptoms in Technicians and Students/Staff.

Group	Subject	No.	Age (year)	Weight (Kg)	Height (m)	Respiratory symptoms (%)
Test	Technicians	10	34 ± 0.09	69.39 ± 0.47	1.69 ± 0.09	72±1.10*
Control	Students and staff	10	37 ± 1.56	70.83 ± 0.89	1.69 ± 0.01	48±0.19

*Data are given as mean ± SEM, *t-test p< 0.05, n = 20*

Table 2: Mean values for PEFR, FVC, FEV1 and FEV1 % between Technicians and Students/Staff.

Group	Subject	No.	PEFR (L/min)	FVC (L)	FEV_1 (L)	FEV1/ FVC	FEV_1 % (L/s)
Test	Technicians	10	74.13±1.07*	3.91±0.17*	3.01±0.18*	0.84±0.14*	76.06±1.19*
Control	Students and Staff	10	82.42±1.70	4.20±0.18	3.53±0.19	0.76±1.19	84.04±0.16

*Data are given as mean ± SEM, *t-test p< 0.05, PEFR = peak expiratory forced rate, FVC = forced vital capacity, FEV_1 = forced expiratory volume in one second, FEV_1 % = forced expiratory volume percentage, n = 20*

DISCUSSION

Lead (Pb) is a known neurotoxin and can pose other significant chronic health effects such as reproductive problems, digestive problems, memory and concentration problems, muscle and joint pain (Ab Latif *et al*. 2015). Therefore, solder that contains lead is considered to be toxic. If lead-containing soldering material is not safely handled, workers may be inadvertently exposed. Potential exposure routes from soldering include ingestion of lead due to surface contamination. The digestive system is the primary means by which lead can be absorbed into the human body. Skin contact with lead is in, and of itself, harmless, but getting lead dust on the hands can result in it being ingested if the hand is not properly washed before eating, smoking, etc., Trenton, (1986). In the same study, Trenton also reported that ingesting even a small amount of lead portends danger since it is a cumulative poison that is not excreted by normal bodily function.

Also, Lead Soldering Safety Guidelines (2018) had reported that soldering with lead or other metals could produce fumes that are hazardous. Additionally, report has shown that using flux containing rosin (also called colophony) produces solder fumes which if inhaled, could result in occupational asthma or may worsen existing asthmatic condition (Lead Soldering Safety Guidelines, 2018). The fumes can also cause eye and upper respiratory tract irritation. Courtney, (1985) and Lead Soldering Safety Guidelines (2018) have also reported that fumes and vapors released during hand soldering with free solder may pose a greater risk to employees. However, when the solder is handled and treated appropriately, there is minimal hazard to any person working with the solder.

Spirometry which is a measure of the integrity of the respiratory muscles (Guyton and Hall, 2016) was used to assess the effects of solder-lead fumes on the respiratory system (CDC, 2019; Pierce, 2005). One of the benefits of spirometry testing is that it can detect abnormalities in lung function even when no signs or symptoms of disease are evident. It can also be used to monitor the effectiveness of medical therapy (USW, 2013). Two measurements are crucial in the interpretation of spirometry result viz-a viz: the forced vital capacity (FVC) – a measurement of lung size (in liters), representing the volume of air in the lungs that can be exhaled following a deep inhalation (Guyton and Hall, 2016). The forced expiratory volume – one second (FEV_1) is the second parameter. This is a measure of how much air can be exhaled in one second following a deep inhalation (Guyton and Hall, 2016). The FEV_1/ FVC ratio is another number on the spirometry test result. It represents the percent of the lung size (FVC) that can be exhaled in one second (USW, 2013).

According to MeSH, (2019) the vital capacity can help make a diagnosis of underlying lung diseases. From the result of our findings, the forced expiratory volume in one second (FEV_1) and the forced vital capacity (FVC) were greatly reduced amongst the technicians. This was on the contrary when compared with the Medical students and staff group who showed no significant change in their lung function, as they were not exposed to the poisonous fumes. Forced expiratory volume measures how much air a person can exhale during a forced breath. The amount of air exhaled is usually measured during first (FEV_1), second (FEV_2), and /or third seconds (FEV_3) of the forced breath. Therefore, FVC is the total amount of air exhaled during the FEV test. Since FEV_1/FVC was decreased as compared to control based on the result obtained, it shows a consistency with an obstructive form of lung diseases which may be asthma or/and chronic obstructive pulmonary disease (COPD) (Thompson *et al.* 2018). This result supports the work of Lee *et al.* (1992) who reported that solderers with 5 or more years of exposure may have a mild obstructive effect apart from smoking, asthma, or age. According to Briton *et al*. (2014), asthma, chronic bronchitis, bronchiectasis and chronic obstructive pulmonary disease are all obstructive lung diseases characterized by airway obstruction.

The peak expiratory flow (PEF) also called peak expiratory flow rate (PEFR) which is the highest forced expiratory flow, was measured using a peak flow meter. From the results obtained, the PEFR for the technicians was significantly lower when compared with the control group. Flow rate decreases when the airways are blocked. This may be caused by a flare-up in lung disease (Natalie, 2017). It has been reported that people with asthma may experience low peak flow rates before they develop breathing symptoms (Chick *et al*. 2012; Yawn *et al*. 2017).The peak flow score indicates whether the airways are narrowed, which could be a sign of asthma attack (NHS, 2018). Measuring the peak flow before and after exposure to a possible asthma trigger, such as allergy or a substance exposed to at work may show if anything in particular causes such symptoms. Normally, the peak flow test is interpreted based on age, sex, and height of individual.

In 2017, Natalie had classified test results as green, yellow, and red zones. Green zone: (80 - 100% of usual flow rate). This zone is considered ideal. Yellow zone: (50 – 80% of usual flow rate). This zone indicates that the airways may be starting to narrow. Red zone: (< 50%). This implies that the airways are severely narrowing. From the result obtained from our subjects, the technicians had a peak flow rate of 74%). This implies that they belong to the Yellow zone, indicating that their airways may be starting to narrow. The control group result based on Natalie zoning principle fell in the Green zone of 82%, implying that their airways are safe.

Measurement of FEV_1/FVC ratio was carried out on the subjects. Results obtained showed that the FEV_1 /FVC for the technicians were 3.0/3.9. This implies that their FEV_1/FVC ratio was 76.9%. This was lower than the control group whose FEV_1/FVC was 3.5/4.2 (83.3%). According to (Chick *et al*. 2012; Yawn *et al*. 2017) when an FEV_1 value is less than 80% of an FVC, it implies that an obstructive lung disease, such as COPD is present. Abnormality ranges from mild (70-79%), moderate (60-69%) to severe (< 60%). Comparatively, from the result obtained from the technicians 76.9% is within the range of mild abnormality. This implies that the observed decrease in the airflow through the lungs among the technicians may be caused by obstructive or restrictive lung diseases.

Solder-lead fumes are highly water soluble and chemically reactive (Environmental Health and Safety, 2019). And due to its high water solubility, over 90% of inhaled solder fumes are absorbed in the upper respiratory tract (Environmental Health and Safety, 2019) and may irritate the mucous membrane Bascom (1991), with a small portion reaching the lungs (Gminski 2011). Earlier research had suggested the possibility of the solder fumes to absorb into fine particles, and this may be present in any environment including the workshops of these technicians, facilitating deposition of the normally soluble gas onto deeper portion of the trachea-bronchial trees (Nielsen, 1982; Robert *et al.* 1994; Jakob *et al.* 2014 and Geoff, 2015). In this study, it was observed that eye irritations, nose irritations, headache, nausea, fatigue and stress were common complaints among the technicians who had exposures to solder-lead fumes. According to Ab Latif, (2015) and Safety & Health (2016) these signs are common attributes of short-term and long-term exposures to solder-lead fumes. Several researches have noted a link between low-level solder fumes exposures and symptoms similar to stomach upsets, skin irritation and headache (AirBench, 2017). Similarly, earlier reports from workplace environments have noted eye irritation, nose irritation, wheezing, lower airway irritation, chest discomfort and increased cough among workers exposed to solder fumes (Uba *et al*. 1989). Reports have also shown that apart from the prevalence of symptoms like eye irritation, exposure to solder-lead fumes can lead to acute hypersensitivity pneumonitis (Ab Latif *et al*. 2015; WHO, 1999 and Raiza *et al*. 2019).

A variety of approaches have been used to study the pulmonary effects of respiratory irritations (Nielsen, 1982; Bascom, 1991). In earlier reports, Gminski *et al*. (2011) had stated that a large experimental life nature and growing number of studies using human volunteers appeared to be the most important sources of knowledge about the pulmonary effects of respiratory irritations. It has been stated that the respiratory tract may be adversely affected, since the major route of exposure (excluding skin contact) is through inhalation (Gupta *et al*. 1991; Palmer & Crane 1997).

In conclusion, the study has shown a slight change in lung capacity and volume amongst solder-lead workers. Although the change in lung function is relatively insignificant, it hardly posed any appreciable decrease in physical activity and capability of the technicians. Upon this study, it is hereby recommended that the workshops and technical factories should be highly ventilated. This would serve as a good control option for reducing the risk of solder-lead exposures.

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