

Full Length Research Paper

Health effects of lead exposure among Jua Kali (informal sector) workers in Mombasa, Kenya: A case study of the “Express” Jua Kali workers

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The objective of this study is to analyze the effects of lead exposure among the Jua Kali workers. Correlation study: relationship between lead exposure and its effects on blood lead levels (BLL), kidney function and haemoglobin levels between the lead-exposed versus the lead un-exposed workers. 162 adult Jua Kali workers participated. Out of 119 exposed workers, 8 (6.72%) were aware of lead while only 3 of them (2.5%) used protective equipment. The highest BLL in the test group was 32 µg/dl with 16 of them (13.45%) having BLL above 10 µg/dl. The mean BLL in this group was 6.76 ± 5.96 . In the control group, the highest BLL was 9 µg/dl with none having BLL above 10 µg/dl. The mean BLL was 2.58 ± 1.69 . The spearman's correlation coefficient was 0.272 significant at 0.05 level. 14 out of 119 (13.45%) exposed workers had impaired glomerular filtration rates (GFR). The mean GFR in the exposed workers was 104.85 ± 16.485 . In the un-exposed workers, 1 out of 43 (2.4%) had impaired GFR. The mean GFR was 109.98 ± 15.408 . The spearman's correlation coefficient was -0.113, not statistically significant. 21 out of 119 (17.6%) lead-exposed workers had haemoglobin (HB) less than 13 g/dl with mean HB of 14.12 ± 1.600 . 1 out of 43 (2.3%) in the control group had an HB of less than 13 g/dl with the mean HB of 14.37 ± 1.34 . Spearman's correlation coefficient of negative 0.321 ($P < 0.05$) implying significant inverse relationship. Recommendations: education on lead and its effects, provision of protective equipments, medical facilities to diagnose and manage lead and other heavy metal toxicity.

Key words: Lead exposure, blood lead levels, glomerular filtration rates, haemoglobin levels.

INTRODUCTION

Lead is a naturally occurring element, the most accessible of the heavy metals in the earth's crust. It is widely distributed and used in numerous industrial processes and domestic appliances (ATSDR, 2005). It is

a poison whose effects have been known for nearly 3000 years and written about by historical figures from the Greek botanist, Nicander, who described the colic and paralysis seen in lead-poisoned people (Pearce, 2007) to the Greek physician, Dioscodes, who wrote that lead makes the mind “give way” (Henretig, 2006). It is one of the largest environmental medical problems in terms of numbers of people exposed and public health toll it takes (Pokras and Kneeland, 2008). In adults, occupational exposure is the main cause of lead poisoning (Needleman, 2004). Exposures to lead can occur through inhalation, ingestion or occasionally skin contact. Lead may be taken in through direct contact with the mouth, nose and eyes (mucous membrane) and through breaks in the skin (Patrick, 2006). About 35 to 40% of inhaled lead dust is deposited in the lungs and about 95% of that goes into the bloodstream. Of the ingested lead, 15% is absorbed

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Abbreviations: ACIH, American Conference of Industrial Hygiene; BLL, blood lead levels; CBD, central business district; CDC, Center for Disease Control; DHHS, Department of Health and Human Services; dl, deciliter; DOSHS, Directorate of Occupational Safety and Health; GFR, glomerular filtration rate; HB, haemoglobin; ml, milliliter; µg, microgram; NIOSH, National Institute of Occupational Safety and Health; PPE, personal protective equipment; WHO, World Health Organization.

into the bloodstream (Karri et al., 2008). The main body compartments that store lead are the blood, soft tissues and bone (Karri et al., 2008). 94% of absorbed lead is stored in bones. Half life of lead in bone is 20 to 30 years and bone can introduce lead in the bloodstream long after the initial exposure is gone (Patrick, 2006).

Lead circulating in the blood can accumulate in the kidney. The toxic effect of lead causes kidney failure by impairing the function of the proximal convoluted tubules (Rubin and Strayer, 2008). Kidney failure is a medical condition in which the kidneys fail to filter out unwanted/toxic materials from the blood. It is biochemically detected by an elevated blood creatinine levels. Lead poisoning of the kidney inhibits the excretion of uric acid predisposing one to gout (Lin and Huang, 1994). Anaemia is a decrease in the number of red blood cells or less than normal quantity of haemoglobin in the blood. Anaemia leads to hypoxia (lack of oxygen) in the organs, because haemoglobin carries oxygen from the lungs to the tissues. Anaemia is one of the most characteristic symptoms that indicate high and chronic exposure to lead. It is due to inhibition of a number of enzymes that are involved in haem-synthesis, and as a result, haem-synthesis is impaired and anaemia develops. Lead also affects iron carrier system through cell membrane of red blood cell (Piomelli, 1981).

Diagnosis and treatment of lead exposure is based on blood lead level (the amount of lead in the blood), measured in microgram of lead per deciliter of blood ($\mu\text{g}/\text{dl}$). The US Centre for Disease Control and Prevention and the World Health Organization state that a blood lead level of $10 \mu\text{g}/\text{dl}$ or above is a cause for concern; however, lead may impair development and have harmful health effects even at lower levels, and there is no known safe exposure level (Shaver and Tong, 1991). Authorities such as the American Academy of Pediatrics define lead poisoning as blood lead levels higher than $10 \mu\text{g}/\text{dl}$ (Ragan and Turner, 2009).

The Jua Kali sector is referred to as the "informal sector" or the micro and small enterprise. Jua Kali literally means hot sun indicating the severe conditions under which the micro entrepreneurs go through. This sector is ever increasing as a result of reduced formal employment in the country. The sector consists of small scale workers who lack access to credit, proper equipments, education, training and good working conditions. They are involved in labour-intensive activities providing cheap goods or services while surviving on low income. Originally restricted to artisans, the term has come to include a number of professions including auto-mechanics, painters, hawkers, water kiosks, repair of goods and market vendors (Orwa, 2007). The researcher conducted a case study on the "Express" Jua Kali workers. According to Mugenda and Mugenda (2003), a case study is an in depth investigation of an individual, group, institution or phenomenon. Most case studies are based on the premise that a case can be located, that is, typical of

many other cases. The primary purpose of this case study is to determine factors and relationships that have resulted in the behavior under study. The "Express" Jua Kali workers are located between Express House along Moi Avenue, Liwatoni Road, Pandya Road and the railway station in Mombasa.

Control group of Jua Kali workers in this study are those who are not occupationally exposed to lead. They were selected along Digo and Nkrumah Roads in Mombasa's Central business district. The purpose of this study was to look into the effects of lead emissions at work-place and its effects on the worker. It specifically sought to find out the effects of lead on the kidney function and haemoglobin levels.

MATERIALS AND METHODS

Research design

This study was done using correlational design: establishing the nature and degree of relationship between lead exposure as the independent variable and blood lead levels, kidney function and haemoglobin levels as the dependent variable. This study compared the dependent variables, that is, BLL, kidney function and haemoglobin levels between the test group versus the control.

Study subjects

The study area was the Express Jua Kali area located between Express Building along Moi Avenue, Liwatoni Road and the railway station in Mombasa as the test population. There were 281 Jua Kali workers located at this site. Out of these workers, 223 of them were occupationally exposed to lead (target population). Occupations considered as lead-exposed are those that directly deal with lead at work, these include:

- 1) Radiator repairers: use lead alloys to fix the radiators
- 2) Lead-acid battery recyclers: both the positive and negative plates contain lead
- 3) Painters: some of the paints contain lead
- 4) Welders: in welding leaded products
- 5) Mechanics: involved in many of the aforementioned jobs

A sample of 141 workers was selected from the population of 223. The figure 141 was arrived at using Atchley's formula (Saunders and Thornhill, 2009).

$$n = \frac{Z^2 pq}{d^2}$$

where n=the desired sample size (target population > 10,000); z=standard normal deviate at the required confidence level; p=proportion in the target population estimated to have the measured character; q=1-p; d=the level of statistical significance set.

In this study, z-statistic is 1.96, and desired accuracy is at the 0.05 level.

$$n = \frac{(1.96)^2 \times (0.5) \times (0.5)}{(0.05)^2} = 384$$

Table 1. Sample population (exposed group).

Occupation	Population	Lead exposure	Sample
Mechanics	86	Yes	54
Painters	27	Yes	17
Panel beaters	42	No	-
Welders	98	Yes	63
Battery recyclers	4	Yes	2
Radiator repairers	8	Yes	5
Glass cutter	6	No	-
Exhaust fitters	10	No	-
Total	281	223	141

Table 2. Sample population un-exposed group.

Occupation	Population	Sample
Second hand book sellers	34	21
Second hand cloth sellers	26	16
Food/Water vendors	8	5
Others	23	14
Total	91	56

Gender

Black ethnicity?

Age in years

Plasma creatinine umol/L

Estimated GFR (ml/min/1.73 m²):

Interpretation (CKD Stage)

Figure 1. Estimated glomerular filtration rate calculator, abbreviated MDRD equation.

Since the target population is less than 10,000, the required sample size will be much smaller. In such case, a final sample estimate (nf) is calculated using the formula as follows:

$$nf = \frac{N}{1-n/N}$$

where n = the desired sample size; N = the estimate of the

population.

$$\frac{384}{1 + \frac{384}{223}} = 141$$

The calculation assumes that data will be collected from all cases in the sample and is based on:

- 1) How confident you need to be that the estimate is accurate.
- 2) How accurate the estimate needs to be.

The sample was selected by stratified random sampling (each strata was represented by the profession e.g. stratum for painters, welders, mechanics) from the 223 exposed workers to represent the test population. To select a sample of 141 workers, we divided 223 by 141 and got a factor of 1.58. The population of each strata was divided by this factor (1.58) to obtain the sample population in Table 1.

A sample of 56 from a target population of 91 in the control group (un-exposed Jua Kali population) was selected again by stratified random sampling along Digo Road and Nkrumah Road on Mombasa Central business district. The figure 56 was also obtained through Atchley's formula (Table 2).

Permission from the directorate of occupational safety and health services, ethical approval from Kenyatta National Hospital and University of Nairobi Ethics and Research Committee (KNH-UoN/ERC) and Jomo Kenyatta University authority were required to conduct the research. Consents from the respondents was requested after they had been informed about the purpose, benefits and risks of the study, and their right to withdraw at any point during the study.

Research instruments

Interviews were done on one on one basis, conducted by well-trained research assistants. Information regarding age, nature and duration of occupation, awareness of lead toxicity, use of protective equipments was sought. Biological monitoring-blood samples were collected by qualified and professional laboratory technologists from Lancet, Kenya. 12 cc of blood sample from each respondent were collected and kept in three labeled bottled containers of 4 cc each for assessing blood lead levels, creatinine levels and haemoglobin levels. The samples were taken to the laboratory on the same day having been kept in a cold box. The samples for lead levels were taken to Lancet Laboratories in South Africa for analysis and results were returned by e-mail as attachments. Creatinine values obtained were converted into estimated glomerular filtration rates (eGFR) using the eGFR calculator. It is the abbreviated MDRD equation (MDRD means modification of diet in renal disease study) which is recommended by NICE and renal association of UK (Figure 1). The data collection was done in August 2012.

Data analysis

Data collected from the interview and the laboratory results (blood lead levels, haemoglobin levels and eGFR) were entered in the excel program, tabulated and analyzed in Microsoft Excel, Statistical Package for Social Science (SPSS) and statistical methods. The mean, median and standard deviations (descriptive analysis) were calculated and the correlation coefficient (inferential analysis) was used to assess the existence of the relationship. The aim of the blood analysis was to compare blood lead levels, haemoglobin levels and kidney function among the test and control group.

Table 3. Relationship between occupations and BLL.

Occupation	N	BLL > 10 µg/dl	Percentage	Mean BLL
Mechanics	48	2	4.2	4.06
Painters	12	2	16.67	6.42
Welders	51	6	11.76	7.47
Battery recyclers	2	0	0	7.00
Radiator repairers	6	5	83.3	22.83

Among those occupationally exposed to lead, the radiator repairers had 83.3% of their workers with high BLL followed by the painters.

Table 4. Relationship between occupations and GFR.

Occupation	N	GFR < 90 ml/min	Percentage of GFR < 90 ml/min	Mean GFR
Mechanics	48	7	14.58	106.58
Painter	12	0	0	109.40
Welder	51	7	13.72	103.25
Battery recyclers	2	0	0	94
Radiator repairers	6	3	50	99

The radiator repairers were the most affected with 50% of them having impaired kidney function.

RESULTS

Response rates

Out of the 141 test Jua Kali workers, 119 consented to participate, giving a response rate of 84.4%. In the control, 43 out of 56 consented to the study giving a response rate of 76.7%.

Awareness of lead toxicity

Out of the 119 exposed Jua Kali workers, only 8 were aware of lead toxicity. This represented 6.72% awareness levels.

Awareness in relation to education

Out of those who were aware of lead toxicity, 3 out of a possible 50 were from primary school representing 5%. 3 out of a possible 44 were from secondary school representing 6.8% and 2 out of a possible 11 were from college, representing 18%.

Use of protective equipments

Only 2.5% of the exposed Jua Kali workers use some form of protective equipment. The maximum blood lead levels (BLL) in the test group was 32 µg/dl, with 16 out of

the 119 exposed workers having BLL more than the recommended levels of 10 µg/dl as per the World Health Organization/Center for Disease Control (WHO/CDC), representing 13.45%. The highest BLL among the control group was 9 µg/dl. None in this group of workers had BLL above 10 µg/dl. The mean BLL of the test group was 6.76 ± 5.926 , while the mean of the control was 2.58 ± 1.679 . Spearman's correlation coefficient was 0.272 ($P < 0.05$; 1-tailed) (Table 3).

Out of 119 lead-exposed workers, 14 had impaired glomerular filtration rates (GFR) of less than 90 ml/min representing 13.3%. 2 out of the 14 had severe kidney damage GFR of 60 and 10 ml/min. Only 1 out of the 43 lead-unexposed workers had impaired GFR representing 2.4%. The mean GFR in the exposed group of workers was 104.85 ± 16.485 , while the mean in the un-exposed group was 109.98 ± 15.408 . The spearman's correlation coefficient was negative 0.113. Correlation was found not significant (Table 4).

The lowest haemoglobin among the test group was 6.10 g/dl. There were 21 lead-exposed workers with haemoglobin below the WHO recommended levels of 13 g/dl representing 17.6%. The lowest haemoglobin levels in the lead-unexposed group was 10 g/dl, only 1 worker was having haemoglobin below 13 g/dl representing 2.3%. The mean haemoglobin levels in the test group was 14.12 ± 1.600 , while the control being 14.37 ± 1.34 . Spearman's correlation coefficient was -0.321, ($P < 0.05$) indicating significant inverse relationship between lead exposure and haemoglobin levels. Hence, null hypothesis was rejected (Table 5).

Table 5. Relationship between occupations and Hb levels.

Occupation	N	HB < 13	Percentage	Mean Hb
Mechanic	48	6	12.5	14.375
Painter	12	1	8.3	14.35
Welder	51	11	21.55	14.13
Battery recycler	2	0	0	14.60
Radiator repairer	6	2	33.3	13.87

The radiator repairers were the most affected with 33.3% of them having haemoglobin of less than 13 g/dl.

DISCUSSION

This study looked at 2 groups of Jua Kali workers: (1) those occupationally exposed to lead (test group) and (2) those not occupationally exposed to lead (control group).

Amongst the test group, this study realized very low awareness level of lead and its effects among the Jua Kali workers (6.7%). This is despite all the international campaigns to ban or reduce lead levels in products and in the environment since 1970s. With education, however, this study revealed that there is a significant improvement of awareness amongst these groups of workers with 18% of those with tertiary level of education being aware of lead and its effects as compared to 5% of those with primary level of education. Since the worker's awareness of lead and its effects is low, it is expected, as was shown in this study, that the use of protective equipment was very low (2.5%).

This study compared the blood lead levels of the 2 groups of workers to see if occupational exposure to lead translates to higher blood lead levels. The study indicated higher BLL in the test group as compared to the control group with over 13% of the test group having BLL above 10 µg/dl (recommended levels by WHO/CDC), while in the control group none had BLL above 10 µg/dl. Although, there was a significant difference in lead levels between the test and the control, previous studies had indicated much higher lead levels. Study done by Njoroge et al. (2008) on environmental and occupational exposure to lead, done in Nairobi, Kenya, the highest BLL was 65 µg/dl with 89% of the test group having high BLL and a mean of 22.5 µg/dl, while 15% of the control group having high BLL, with a mean of 6.75 µg/dl. The high BLL in the earlier study (Njoroge et al., 2008) could be explained by:

- 1) Nairobi is a more industrial town than Mombasa, possibly with more lead emissions
- 2) The study was done much earlier in 2006, at that time, international awareness and actions against lead emissions and toxicity was less than at this present times. Hence, most products like paints and petroleum had higher lead levels compared to the present times.

This study also compared the kidney function of the test versus the control group. Lead is a known poison to

the kidney causing injury to the proximal tubules of the nephron. 13.3% of the test group had impaired GFR as compared to 2.4% of the control, with a correlation coefficient of -0.113; the difference is not statistically significant. Related study done by kemal et al. (2005) on the effects of lead exposure among battery workers, in Addis Ababa, Ethiopia, showed no significant correlation between lead exposure and kidney function. Similarly, Karimooy et al. (2010) in Mashad, Iran, found no significant correlation between lead exposure and kidney function while studying workers at the traditional tiles factory, on effects of occupational lead exposure on kidney function.

This study also looked at the effects of lead on haemoglobin by comparing the 2 groups of workers. Lead inhibits certain enzymes necessary for haem-synthesis. In this study, 17.6% of the test population had haemoglobin levels less than 13 g/dl as compared to the control which had 2.4%, showing that lead had an effect on haemoglobin levels.

As much as the occupation of lead-exposed workers is concerned, the radiator repairers were the most affected with more than 80% of them having high BLL, 50% of them with impaired kidney function and more than 30% with HB less than 13 g/dl. This is because in repairing the radiator, these workers heat the lead until it melts with lead vapour, then mix with tin to form an alloy. During this process they inhale the lead vapour. To make it worse, the radiator repairers were located in a small, poorly ventilated room.

Conclusion

This study looked at the effects of lead exposure on Jua Kali workers. It specifically sought to find out:

- 1) The level of awareness of lead and its effects among Jua Kali workers
- 2) The effects of lead exposure on the blood lead levels.
- 3) The effects of lead exposure on the kidney function.
- 4) The effects of lead exposure on the haemoglobin levels.
- 5) The prevalence of lead toxicity amongst different occupations of the Jua Kali workers.

In view of the findings of this research, the study concluded that:

- 1) There is low level of awareness of lead and its effects amongst Jua Kali workers, with those of lower educational level more affected.
- 2) There is a significant relationship between lead exposure and blood lead levels, with 13.5% of the exposed workers having high BLL (>10 µg/dl). None of the workers had >40 µg/dl.
- 3) There is no significant relationship between blood lead levels and kidney function although 13.3% of the exposed workers had impaired kidney damage, 2 of them having

severe kidney disease (GFR of 60 and 10).

4) There is a significant inverse relationship between lead exposure and haemoglobin levels with 17.6% of exposed workers having anaemia, 1 having severe anaemia (hb of 6.10).

5) Amongst the exposed workers, radiator repairers had the highest BLL (83% of them with >10 µg/dl) followed by painters 17%. The radiator workers were the most affected with 50% having impaired kidney function and 33% being anaemic.

RECOMMENDATIONS

Intervention measures need to be put in place to protect Jua Kali workers from over exposure to lead. These measures include:

- 1) Workers education on lead and its effects.
- 2) Provision of free or subsidized personal protective equipments (PPEs) e.g. facial mask, gloves and gowns
- 3) Provision of water for washing of the protective clothing and bathing.
- 4) Establishment of engineering controls
- 5) Regular medical examination to assess lead levels and its effects in the exposed population.
- 6) Establishing a specialized medical center as a referral for the diagnosis and management of lead and other heavy metal toxicity.
- 7) A detailed study to be done to assess the actual amounts of lead levels at the place of work (occupational lead levels) and comparing these levels with the environmental lead levels.

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