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Article

Group-specific Differences in Blood Lead Levels among Occupationally Exposed Workers in Greater Banjul Area, The Gambia

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Abstract: Occupational lead (Pb) exposure continues to be an important public health problem globally, yet data is lacking on the associated risks and resources available for the prevention of Pb related diseases in low middle income countries (LMICs) like The Gambia. In this study, we used a case-control design to compare blood lead levels (BLLs) between the exposed (auto repair workers) and unexposed (healthcare workers) populations in The Greater Banjul Area. The data was analyzed using Chi square test of independence to determine the characteristic factors associated with BLL. Multivariate logistic regression was used to test the relationship between BLLs for auto repair and healthcare workers and their experiences. The results of this study indicated 82.1% of cases had higher BLLs compared to 52.9% of controls. Also, the proportion of workers with elevated BLLs was higher for certain factors including more than 80% of those with greater than 10 of years job experience, more than 70% of those who worked greater than 5 days a week, worked more than 8 hours per day, did not use personal protective equipment (PPE), were illiterate or had no formal education, and smoked or ate at work. The study results have implications for policies and practice in the auto repair industry and related workplaces in The Gambia and other LMICs with similar settings. Based on the findings of this study, it is essential to initiate discussions to establish national occupational health policies in The Gambia aimed at protecting workers and the general population.

Keywords: Blood Lead Levels, Lead Exposure, Auto Mechanics, Workplace Health, Low Middle Income Countries, Healthcare Workers

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1. Introduction

Lead (Pb) is one of the most widely distributed environmental pollutants with potential for adverse health effects to humans [1]. Occupational Pb exposure is essentially unregulated in many developing countries, often with no monitoring of exposure [2]. As a pollutant with cumulative effects, exposed individuals may be at risk of livelong negative heath consequences [3]. When absorbed into the bloodstream, Pb is distributed to many organs, especially the kidney and liver. It can then build up in the bones and harm a variety of organs, including the liver, heart, immune system, kidneys, and male gonads [4]. A syndrome of acute poisoning can follow a brief period of high exposure to Pb. These include abdominal colic, constipation, fatigue and central nervous system dysfunction. At lower doses, headaches and personality changes may be indications neurologic toxicity. Acute encephalopathy with coma and convulsions may occur with extreme exposures [2]. In children, exposure to Pb is associated with impairment of neurodevelopmental, decreased attention span, dyslexia, hyperactivity disorder, school failure, and increased future risk for drug abuse, criminal behavior and incarceration [5]. In adults, Pb can cause neurodegenerative diseases like Alzheimer's or Parkinson disease, neurobehavioral impairment, hypertension, renal disease, cardiovascular disease, stroke and premature death [5, 6].

Lead exposure continue to significant contribute to increases in morbidity and mortality of the leading global burden of disease. Recent studies have found a rise in the trend of deaths resulting from Pb exposure globally from 1990 to 2019 varying considerably with age, sex, region, and subsequent disease [7-9]. Xu et al. found deaths to increase by 70.19% principally due to ischemic heart disease (IHD), stroke, and hypertensive heart disease [8]. Age standardized mortality rate of chronic kidney disease attributable to Pb exposure showed an upward trend with an annual average percentage change of 0.5 mostly affecting the elderly especially males [7]. In their study, evaluating the temporal-spatial trend of disease burden caused by Pb exposure in 204 countries and territories, Zhou et al. found the increase to be from 0.53 to 0.90 million. In the same period, the number of disability-adjusted life-years (DALYs) due to Pb exposure increased by 35.26% (16.02 to 21.68 million [9]) with the fastest growing DALYs attributable to IHD, stroke, diabetes and kidney disease [2]. Rezaee et al. found the highest Pb exposure attributable age-standardized DALYs to result from IHD, stroke, hypertensive heart disease, and idiopathic developmental intellectual disability (IDII) [10]. Globally, 2.72 million IDII DALYs were attributable to Pb exposure in 2019 with an age-standardized DALYs rate of 35.70/100,000. Children and adolescents and those from low- and middle-income countries account for the highest rates [11]. No level of Pb is considered to be safe [5]. Consequently, the World Health Organization (WHO) has identified Pb as one of 10 chemicals needing action by member countries to protect the health of workers, children, and women of reproductive age [12].

Sources environmental Pb include mining, smelting, manufacturing of Pb batteries, automobiles, ships, solder, Pb pigments, Pb-based paint, deposition from leaded gasoline, recalcitrant drinking water infrastructure and contaminated consumer products [13]. In the general population, Pb exposure is mostly caused by gasoline, paint, solder, and pipes, whereas occupational exposure is caused by the production of batteries, steel welding or cutting activities, printing, and construction [14]. Leaded gasoline is a major source of environmental Pb, especially in Low- and Middle-Income Countries (LMICs) where environmental and occupational regulations are rare (Kordas et al., 2018). Where regulations exist in LMICs, they are weakly or unevenly enforced (Kordas et al., 2018). Albeit, in The Gambia, gasoline-based Pb importation was banned in 2008, Pb is persistent in the environment and there could be some Pb residue within the environment, especially areas close to major motorways. A study in Benin City, Nigeria showed that soils within 10 meters of major roadways had the highest Pb levels and the further from the road, the lower the concentration of Pb in the soil [15]. Most importantly, with increasing economic growth, there are proliferations of unregulated industries like welding, auto repair, and battery recycling in many LMICs, including The Gambia (Kordas et al., 2018). The amount of Pb emitted from most industries or workshops are not known, but studies in Bangladesh and Nigeria have shown elevated exposure among occupational workers in these industries [16, 17].

Occupational exposures to Pb remains an important preventable source of Pb exposure [18]. Gebrie et al. found the mean blood level (BLL) of the exposed group to be significantly higher than that of the unexposed group and laborers who regularly used personal protective equipment had significantly lower BLLs than those who did not [19]. Exposure to Pb in mining has been found to potentially alter some serum liver enzymes, lipid profile, and lipoproteins levels [4]. Another study in Ethiopia, found noticeably high BLLs of automotive-garage workers influenced by their occupational practices [2]. The Pb concentrations in the air at the occupational environment can have a direct relationship with BLL. Eriksen Hammer et al. in their biological monitoring of BLL found correlation between concentrations of Pb in the blood with that in the air at the workplace though this was not significantly different from the reference group [20].

Nationally, there is no study in The Gambia that assesses BLLs among occupational groups. In resource limited countries like The Gambia, where such essential information is lacking, mortality and disability due to Pb exposure could be high and go unnoticed. What is intuitively clear is that to curb death and disability due to Pb in LMICs, there is a need to identify occupational groups associated with elevated BLLs [21]. This can trigger discussions on developing occupational health policies and regulations. It can also provide recommendations to occupational groups to require the use of personal protective devices.

Working in the auto repair industry involves interaction with car batteries, welding fumes, paint, scrap metals, and soil contaminated by previous gasoline use. Such interactions with exposed workers can lead at concentrations higher than would have ordinarily been available in the environment and the associated health effects on exposed occupational populations can be adverse [16, 17]. In many LMICs, the auto repair industry is diverse and is not standardized through policies which leaves the protection of employees to the responsibility of employers where the costs of protection can be costly [21]. Strict adherence to personal hygiene practices, use of personal protective equipment (PPE), availability of information on prevention of Pb exposure and promulgation of legislation on protecting workers from Pb exposure can to a great extent improve workers wellbeing.

In The Gambia, especially in the Greater Banjul Area, there is a proliferation of auto repair workshops engaging in welding/panel beating, vehicle painting, and radiator repairs. Battery repairing and recycling, though not usually registered, are also taking place on a considerable scale. The magnitude of exposure in different occupational groups, as well as factors that influence such were never studied in The Gambia and the West African subregion. Also, the level of knowledge of workers on the risks of exposure to Pb and methods of prevention is unknown. Presently, there are no safety laws or policies to promote and protect the health of workers in such occupational settings. Occupation-specific interventions to protect workers exposed to Pb can be successfully implemented when they are identified. Therefore, it is important to measure BLLs among workers in the auto repair industry as well as to identify the factors responsible for differences in BLLs between different occupational groups.

2. Materials and Methods

Human Subjects Institutional Review Board approval for this study was issued by the Joint Gambia Government/Medical Research Council Ethics Committee, The Gambia, Protocol Number: SCC 1602v1.1.

One hundred forty-five (145) exposed and 68 unexposed workers from the Greater Banjul Metropolitan area participated in the study. The sampling method used for this study was simple random sampling to select the control group (healthcare workers) and the cases including car and electronic repairers, painters, welders, and healthcare workers. For the cases, tax registries at Brikama Area Council (BAC), Kanifing Municipal Council (KMC) and Banjul City Councils (BCC) were used to select radiator repairers, painters, and panel beaters/welders. For the controls, healthcare workers were selected using the staff role at Kanifing General Hospital. Healthcare worker group was selected as a reference population because exposure to Pb in uncommon in the healthcare setting. In both instances, personal information were exported to Microsoft Excel® and Random Number

Generator was used to randomly select study participants. As battery recyclers are unlikely to be listed consistency on tax registries or other government lists; a list was compiled using a snowball approach. The compilation started with known recyclers/repairers. Information concerning others was subsequently gathered until a list of known recyclers was obtained. This list was used to randomly select participants in this category.

There were two sources of data for this study, blood samples and a questionnaire: 1) BLLs was measured in car and radiator repairers, painters, battery recyclers, welders and healthcare workers using the LeadCare® II Blood Lead Testing System. Questionnaire was administered after workers' consent to participate in the study and capillary blood sample taken. The questionnaire focused on individual biodata, occupational history with focus on previous potential Pb exposed jobs, use of protective devices, hygiene, smoking and eating in the workplace and major job tasks and length of workday and work week.

The LeadCare® II Blood Lead Testing System that was used for testing blood samples is a simple point-of-care system that allows healthcare professionals to test at risk populations quickly and accurately [22, 23]. The LeadCare II® System reports blood lead values between 3.3 μg/dL and 65 μg/dL. The Center for Disease Control and Prevention (CDC) has established 5 μg/dL as the "reference level" for lead in blood. BLLs above 5 μg/dL indicate 'elevated' lead exposure [24]. To maximize accurate test results the test kits come with 'positive' and 'negative' calibration systems. The LeadCare II® was calibrated before the start of each workday. It was also recalibrated after testing for every 30 blood samples. BLLs were recorded on the questionnaire sheet.

The independent variables in this study were type of occupations; exposure variables such as personal hygiene, smoking and eating at work; work experience; job tasks and average length of time per job task; age, the use of PPE and job processes for which workers use personal protective devices. On the other hand, the dependent variable in this study was the BLL, which was categorized into normal (<5 μg/dL), moderate (5 – 9 μg/dL), and high (>10 μg/dL).

Data was collected by a trained laboratory technician. Graduate students from the University of The Gambia (UTG) Public and Environmental Health program administered the survey questionnaires. The field data collection was supervised by the Principal Investigator (PI) and Co-Investigators.

3. Results

As shown in Table 1, 47% of controls had normal BLLs compared to 17.9% of the cases. Fewer participants in the controls group (29.4%) had moderate BLLs compared to more than half of the cases (51.1%). The number of participants with moderate BLLs were 45.4% and 43.2% for single and married participants respectively. Fewer participants who were single (25%) were categorized as having high BLLs than those who were married (33.3%). Thus, more participants who were single (29.6%) were categorized as having normal BLLs compared to those who were married (23.5%). Similarly, more participants who did not live with family (30.4%) had normal BLLs compared to those living with family (26.8%). More than 40% of both of those who lived with family and those who did not live with family had moderate BLLs. As for BLLs in respect of family sizes, participants with family sizes not more than two had the highest (32.1%) representation among those with high BLLs, followed by those with more than 10 (27.6%). Majority of participants with family sizes of 3 – 10 members (32.2%) were categorized as having normal BLLs. Similarly, the results also depicted a disproportionate increase in the number of people with high levels of BLL as the level of education drops. The participants who could not read and write (42.2%) were categorized as having high BLLs whilst the majority of those who could read and write (30.9%) were categorized as having normal BLLs. The proportion of participants with high BLLs among those with no formal education, primary, secondary and tertiary levels of education were 38%, 30.5%, 28.2% and 12.5% respectively. As for the proportion of participants with BLLs <5μg/dL, 16% had no formal education, 21.7% primary level, 22.4% secondary level and 65.6% with tertiary level education.

Table 1. Socio-demographic Characteristics of Study Population according to Blood Pb Level (μg/dL)

Variable	Blood Pb Level (μg/dL) N (%)		
	<5μg/dL	**5 - 9μg/dL**	**>10 μg/dL**
Study group			
Exposed	26 (17.9)	74 (51.1)	45 (31.0)
Unexposed	32 (47.1)	20 (29.4)	16 (23.5)
Age			
≤20	10 (25.0)	17 (42.5)	13 (32.5)
21-30	27 (29.7)	47 (51.7)	17 (18.6)
31-40	16 (32.7)	16 (32.7)	17 (34.6)
41-50	3 (15.8)	7 (36.8)	9 (47.4)
>50	2 (14.3)	7 (50.0)	5 (35.7)
Gender			
Male	46 (24.0)	88 (45.8)	58 (30.2)
Female	12 (57.1)	6 (28.6)	3 (14.3)
Ethnicity			
Fula	8 (24.2)	22 (66.7)	3 (9.1)
Jola	9 (21.4)	19 (45.3)	14 (33.3)
Mandinka	27 (40.3)	21 (31.3)	19 (28.4)
Wollof	7 (14.6)	21 (43.8)	20 (41.6)
Other	7 (30.4)	11 (47.8)	5 (21.8)
Marital status			
Single	32 (29.6)	49 (45.4)	27 (25.0)
Married	24 (23.5)	44 (43.2)	34 (33.3)
Divorced	2 (100.0)	0 (0.0)	0 (0.0)
Separated	0 (0.0)	1 (100.0)	0 (0.0)
Live with family			
Yes	51 (26.8)	83 (43.7)	56 (29.5)
No	7 (30.4)	11 (47.8)	5 (21.8)
Size of family			
0-2	7 (25.0)	12 (42.9)	9 (32.1)
3-10	28 (32.2)	35 (40.2)	24 (27.6)
>10	23 (23.5)	47 (48.0)	28 (28.5)
Read and write			
Yes	52 (30.9)	74 (44.1)	42 (25.0)
No	6 (13.3)	20 (44.5)	19 (42.2)
Level of education			
No formal education	8 (16.0)	23 (46.0)	19 (38.0)
Primary	10 (21.7)	22 (47.8)	14 (30.5)
Secondary	19 (22.4)	42 (49.4)	24 (28.2)
Tertiary	21 (65.6)	7 (21.9)	4 (12.5)

N = Frequency

The comparison of the socio-demographic characteristics of cases and controls in relation to BLL (μg/dL) is shown in Table 2. Even though the P-values for most of the categories were not significant at 0.05 confidence interval (CI), the proportion of participants with elevated BLLs was found to be higher among the cases than the controls for almost all the categories and subcategories. For both cases and controls, the proportion of participants with high BLLs increased with increases in age from the 21-30, 31-40, and 41-50 categories. The age group with the highest proportion of those with high BLLs was 41-50 for both cases and controls – 50% and 44 % respectively. The proportion of age groups with the highest proportion of participants with normal BLLs were the <20 years (25%) for the cases and the 21-30 years (53.4%) for the controls. For the cases, those with moderate BLLs ranged between 42.5% - 60.7% among all age groups whilst for the controls, it ranged between 20.8% – 40%. There were no females among the cases. Among controls, 57.1% had normal BLLs whilst 14.3% had high BLLs. Among cases, the highest proportion with high BLLs were the Wollof (48.4%) ethnic group followed by the Jola (35.2%) and the Mandinka (27.7%) whilst the highest proportion with normal BLLs were the Mandinka (30.6%) followed by the Jola and others with 17.7% each. As for the controls the highest proportion of participants with high BLLs were the Mandinka (29%), followed by the Wollof (26.7%) and the Jola (25%). Those with moderate BLLs among cases ranged from 41.7 – 72% whilst among controls the range was from 16.7% - 50%. For both cases and controls more singles had lower BLLs than married participants.

Table 2. Socio-demographic Characteristics according to Occupational Groups in relation to Blood Pb Level (μg/dL)

Variable	Blood Pb Level (μg/dL) N (%) EXPOSED			P-value	Blood Pb Level (μg/dL) N (%) UNEXPOSED			P-value
	<5μg/dL	5-9μg/dL	>10 μg/dL		<5μg/dL	5-9μg/dL	>10μg/dL	
Age								
≤20	10 (25.0)	17 (42.5)	13 (32.5)		-	-	-	
21-30	11 (18.0)	37 (60.7)	13 (21.3)	0.360	16 (53.4)	10 (33.3)	4 (13.3)	0.315
31-40	3 (12.0)	11 (44.0)	11 (44.0)		13 (54.2)	5 (20.8)	6 (25.0)	
41-50	1 (10.0)	4 (40.0)	5 (50.0)		2 (22.2)	3 (33.3)	4 (44.4)	
>50	1 (11.1)	5 (55.6)	3 (33.3)		1 (20.0)	2 (40.0)	2 (40.0)	
Gender								
Male	26 (17.9)	74 (51.0)	45 (31.1)	-	20 (42.5)	14 (29.8)	13 (27.7)	0.413
Female	-	-	-		12 (57.1)	6 (28.6)	3 (14.3)	
Ethnicity								
Fula	4 (16.0)	18 (72.0)	3 (12.0)		4 (50.0)	4 (50.0)	0 (0.0)	
Jola	6 (17.7)	16 (47.1)	12 (35.2)	0.044	3 (37.5)	3 (37.5)	2 (25.0)	0.519
Mandinka	11 (30.6)	15 (41.7)	10 (27.7)		16 (51.6)	6 (19.4)	9 (29.0)	
Wollof	2 (6.1)	15 (45.5)	16 (48.4)		5 (33.3)	6 (40.0)	4 (26.7)	
Other	3 (17.7)	10 (58.8)	4 (23.5)		4 (66.6)	1 (16.7)	1 (16.7)	
Marital status								
Single	22 (24.2)	44 (48.4)	25 (27.4)		10 (58.8)	5 (29.4)	2 (11.8)	
Married	4 (7.6)	29 (54.7)	20 (37.7)	0.110	20 (40.8)	15 (30.6)	14 (28.6)	0.318
Divorced	-	-	-		2 (100.0)	0 (0.0)	0 (0.0)	
Separated	0 (0.0)	1 (100.0)	0 (0.0)		-	-	-	
Live with family								
Yes	25 (19.4)	64 (49.6)	40 (31.0)	0.400	26 (42.6)	19 (31.2)	16 (26.2)	0.085
No	1 (6.3)	10 (62.5)	5 (31.2)		6 (85.7)	1 (14.3)	0 (0.0)	

Size of family								
0-2	1 (4.8)	11 (52.4)	9 (42.8)	0.314	6 (85.7)	1 (14.3)	0 (0.0)	0.088
3-10	7 (15.6)	23 (51.1)	15 (33.3)		21 (50.0)	12 (28.6)	9 (21.4)	
>10	18 (22.8)	40 (50.6)	21 (26.6)		5 (26.4)	7 (36.8)	7 (36.8)	
Read and write								
Yes	21 (19.1)	58 (52.7)	31 (28.2)	0.408	31 (53.5)	16 (27.6)	11 (18.9)	0.025
No	5 (14.3)	16 (45.7)	14 (40.0)		1 (10.0)	4 (40.0)	5 (50.0)	
Level of education								
No formal education	6 (15.4)	19 (48.7)	14 (35.9)		2 (18.2)	4 (36.4)	5 (45.4)	
Primary	10 (21.7)	22 (47.8)	14 (30.5)	0.012	-	-	-	0.115
Secondary	6 (10.9)	32 (58.2)	17 (30.9)		13 (43.4)	10 (33.3)	7 (23.3)	
Tertiary	4 (80.0)	1 (20.0)	0 (0.0)		17 (63.0)	6 (22.2)	4 (14.8)	

N = Frequency, P-Value < 0.05 is significant

Table 3 shows the BLLs (μg/dL) of participants according to work-related exposure variables – years of work, hours of work per day, days of work per week, smoker or ex-smoker, eat lunch/food at work, repair radiators, repair batteries, panel beat/weld vehicle parts and paint/spray cars. The majority of cases with high BLLs were among those with work experiences of 1-3 years (47.4%) followed by those with ≥10 years (32.4%) and 4-6 years (29%). However, among the controls, the majority of those with high BBLs were found among those with ≥10 years of work experience (42.1%), followed by those with 1-3 years (30.8%) and 4-6 years (18.1%). Cases with 7-9 years of work constituted the majority (75%%) among those with moderate BLLs followed by those with <1 year (60%) and ≥10 years (54.6%). Among controls, participants <1 year of work constituted the majority (66.7%) of those with moderate BLLs followed by 7-9 years (31.8%) and 1-3 years (30.8%) categories. As regards normal BLLs, among cases, participants with 1-3 years of work experience constituted the majority (26.3%) whilst among controls those with 7-9 years of work experience constituted the majority (59.1%).

Table 3. Blood Pb Level (μg/dL) of Participants according to Work-related Exposure Variables

Variable	Blood Pb Level (μg/dL) N (%)			P-value	Blood Pb Level (μg/dL) N (%)			P-value
	EXPOSED				UNEXPOSED			
	<5μg/dL	5-9μg/dL	>10 μg/dL		<5μg/dL	5-9μg/dL	>10μg/dL	
Years of work								
<1	1 (20.0)	3 (60.0)	1 (20.0)		1 (33.3)	2 (66.7)	0 (0.0)	
1-3	5 (26.3)	5 (26.3)	9 (47.4)	0.209	5 (38.4)	4 (30.8)	4 (30.8)	0.313
4-6	8 (25.8)	14 (45.2)	9 (29.0)		6 (54.6)	3 (27.3)	2 (18.1)	
7-9	2 (16.7)	9 (75.0)	1 (8.3)		13 (59.1)	7 (31.8)	2 (9.1)	
≥10	10 (13.0)	42 (54.6)	25 (32.4)		1 (33.3)	4 (21.1)	8 (42.1)	
Hours of work per day								
4-5	-	-	-	0.741	1 (100.0)	0 (0.0)	0 (0.0)	0.685
6-8	0 (0.0)	1 (50.0)	1 (50.0)		27 (49.1)	16 (29.1)	12 (21.8)	
>8	26 (18.2)	73 (51.1)	44 30.7)		4 (33.4)	4 (33.3)	4 (33.3)	
Days of work per week								
1-6	10 (12.4)	41 (50.6)	30 (37.0)	0.070	30 (49.2)	18 (29.5)	13 (21.3)	0.405
7	16 (25.0)	33 (51.6)	15 (23.4)		2 (28.6)	2 (28.6)	3 (42.8)	
Smoker or ex-smoker								
Yes	12 (19.1)	30 (47.6)	21 (33.3)	0.770	5 (26.3)	9 (47.4)	5 (26.3)	0.068
No	14 (17.1)	44 (53.7)	24 (29.2)		27 (55.0)	11 (22.5)	11 (22.5)	

Eat lunch/food at work								
Yes	26 (18.1)	74 (51.4)	44 (30.5)	0.327	29 (46.0)	20 (31.8)	14 (22.2)	0.301
No	0 (0.0)	0 (0.0)	1 (100.0)		3 (60.0)	0 (0.0)	2 (40.0)	
Repair radiators								
Yes	14 (21.2)	35 (53.0)	17 (25.8)	0.385				
No	12 (15.2)	39 (49.4)	28 (35.4)					
Repair batteries								
Yes	8 (19.5)	17 (41.5)	16 (39.0)	0.320				
No	18 (17.3)	57 (54.8)	29 (27.9)					
Panel beat/weld vehicle parts								
Yes	10 (16.4)	30 (49.2)	21 (34.4)	0.741				
No	16 (19.1)	44 (52.3)	24 (28.6)					
Paint/spray cars								
Yes	8 (27.6)	18 (62.1)	3 (10.3)	0.021				
No	18 (15.5)	56 (48.3)	42 (36.2)					

N = Frequency, P-Value < 0.05 is significant

BLLs in relation to number of hours worked per day among cases: no participant worked less than five hours, only two worked 6-8 hours (one moderate BLL, one high BLL). The rest of the cases worked more than 8 hours a day. More than half (51.1%) of those with >8 hours had moderate BLL whilst 30.7% had high BLL and 18.2% had normal BLLs. One control who worked 4-5 hours a day, had normal BLL. The majority of the controls worked 6-8 hours a day. Of these, about half (49.1%) had normal BLLs, 29.1% moderate and 21.8% high. For controls who worked more than 8 hours a day, one-third had normal, moderate or high BLLs.

The repair of radiators and batteries, panel beating or welding of vehicle parts and the painting or spraying of cars are occupational activities unique to the exposed (case group), and this is shown in Table 3. Responses to these activities were dichotomized (Yes = the activity is conducted by the response; No = the activity is not conducted by the responder). Under the category of whether the participants repair radiators, those who answered 'Yes' (21.2%) had a higher proportion with normal BLLs than those who said 'No' (15.2%). Those who answered 'Yes' (53%) had a higher proportion with moderate BLLs but a lower (25.8%) proportion with high BLLs while those who answered 'No' had a higher (35.4%) proportion with high BLLs and a lower (49.4%) proportion with moderate BLLs. As for those who do panel beating or weld vehicle parts, those who answered 'Yes' in performing the task had a higher proportion (34.4%) with high BLLs and a lower (16.4%) proportion with normal BLLs compared to those who responded 'No' (28.6%). The proportion of participants with moderate BLLs was 49.2% and 52.3% for those who answered 'Yes' and those who answered 'No' to whether they beat panels or weld vehicle parts respectively. On the other hand, participants who repaired batteries had a higher proportion (39%) with high BLLs than those who did not (27.9%) whilst more (54.8%) who did not repair batteries had moderate BLLs than those who repaired batteries (41.5%). Regarding the question on whether the participant paint or spray cars, those whose answer was 'Yes' had a lower proportion (10.3%) than those whose answer was 'No'. The proportion of participants with normal (27.6%) as well as moderate (62.1%) BLLs was higher among those who paint cars than those who did not (15.5% and 48.3% respectively).

Table 4a shows BLLs and the use of PPE. Only about 4% of cases used PPEs while working on radiators and none of them had elevated BLL. Of those who were not using PPEs, 32.2% had high BLLs, 51.4% moderate, and 16.4% normal. Similarly, one participant with elevated BLL used PPEs when working on batteries. Of the rest who did not use PPEs, 30.5% had high BLLs, 51.4 with moderate BLLs and 18.1% normal. About 12% of participants used PPEs while welding. The proportion of participants who used PPEs while painting was also about 12%. Of this, the proportions with normal, moderate and high BLLs were 25%, 62.5% and 12.5% respectively. Among painters, who did not use PPEs, the proportions of participants with normal, moderate and high BLLs were 17.1%, 49.6% and 33.3% respectively.

Table 4a. Blood Pb Levels according to the Type of Personal Protective Equipment Used by Different Groups

Variable	Blood Pb Level (μg/dL) N (%) EXPOSED			P-value	Blood Pb Level (μg/dL) N (%) UNEXPOSED			P-value
	<5μg/dL	5-9μg/dL	>10μg/dL		<5μg/dL	5-9μg/dL	>10μg/dL	
Used PPE when working on radiators								
Yes	3 (60.0)	2 (40.0)	0 (0.0)	0.033				
No	23 (16.4)	72 (51.4)	45 (32.2)					
Used PPE when working on batteries								
Yes	0 (0.0)	0 (0.0)	1 (100.0)	0.327				
No	26 (18.1)	74 (51.4)	44 (30.5)					
Used PPE when wielding vehicle parts								
Yes	2 (13.3)	8 (53.3)	5 (33.4)	0.886				
No	24 (18.5)	66 (50.8)	40 (30.8)					
Used PPE when painting cars								
Yes	4 (25.0)	10 (62.5)	2 (12.5)	0.228				
No	22 (17.1)	64 (49.6)	43 (33.3)					

Frequency, PPE = Personal protective equipment, P-Value < 0.05 is significant

The multinomial logistic regression model of BLLs among occupational groups is shown in Table 4b. The model shows that the age categories 31-40, 41-50, and >50 have 25%, 79% and 52% increased risk of high BLLs than the reference group (age ≤20) whilst the age category 21-30years had decreased (46%) risk of high BLLs. The risk of having moderate and high BLLs (19% and 93% respectively) was higher for participants who could not read and write compared to those who can. Again, the risk of a participant having high BLL was highest among participants with more than 10 years of work experience than the reference group (1-3 years of experience) while those with 4-9 years of work experience (25%) had a decreased risk. Participants above 10 years of experience were about four times more at risk of having moderate BLLs whilst the risk for the 4-9 years was 73%. The risk for smokers having high BLLs was 1% more than nonsmokers and with a decreased (26%) risk of having moderate BLLs. The risk of having high BLLs is 55% and 94% lower among those who repair radiators and those who paint or spray cars respectively while it is increased for those who do panel beating or weld cars (11%) and those who repair batteries (68%). There was a more than 30% decreased risk of having moderate BLLs for all categories (radiator and battery repairers, welders or panel beaters and painters). There was 71% and 40% increased risk of being with high BLLs for participants who used PPEs when wielding vehicle parts and for those painting cars respectively.

Table 4b. Multinomial Logistic Regression Model of Blood Pb Levels among Occupational Groups

Variable	Blood Pb Level (μg/dL) RRR (95% CI)	
	5-9μg/dL	**>10μg/dL**
Age		
≤20	Reference	Reference
21-30	1.32 (0.38, 4.60)	0.51 (0.12, 2.13)
31-40	0.98 (0.16, 6.15)	1.25 (0.17, 9.33)
41-50	1.06 (0.07, 15.10)	1.79 (0.11, 29.40)
>50	1.51 (0.11, 20.57)	1.29 (0.07, 23.88)
Read and write		
Yes	Reference	Reference
No	1.15 (0.35, 3.84)	1.83 (0.49, 6.87)
Years of work		
1-3	Reference	Reference
4-9	1.65 (0.36, 7.43)	0.70 (0.14, 3.52)
≥10	3.58 (0.67, 19.10)	1.82 (0.28, 11.65)
Smoker/ex-smoker		
Yes	0.73 (0.27, 1.96)	1.08 (0.36, 3.26)
No	Reference	Reference
Repair radiators		
Yes	0.72 (0.24, 1.96)	0.36 (0.11, 1.21)
No	Reference	Reference
Repair batteries		
Yes	0.60 (0.18, 2.00)	1.51 (0.42, 5.44)
No	Reference	Reference
Panel beat/weld		
Yes	1.13 (0.34, 3.78)	1.25 (0.34, 4.64)
No	Reference	Reference
Paint/spray cars		
Yes	0.55 (0.12, 2.60)	0.06 (0.01, 0.66)
No	Reference	Reference
Used PPE when wielding vehicle parts		
Yes	Reference	Reference
No	0.62 (0.07, 5.40)	0.32 (0.03, 3.47)
Used PPE when painting cars		
Yes	Reference	Reference
No	1.18 (0.15, 9.40)	0.60 (0.03, 13.77)

RRR: Relative Risk Ratio, CI: Confidence Interval

4. Discussion

This pilot study of occupationally exposed workers found concentration of BLLs is higher among auto repair workers than healthcare workers. Similar studies show elevated mean blood Pb levels of the automobile technicians and Pb acid battery workers in Nigeria and Bangladesh respectively [16, 17]. On the other hand, one in two of the cases had moderate BLLs, it is one in three among the controls. This may suggest that the controls might also be exposed to some level of Pb both within and outside their work environment. Environmental pollution by Pb caused by the introduction of tetraethyl Pb in gasoline has been a concern in LMICs. It is known that Pb can persist in the environment which makes a lot of sense in this pilot data because The Gambia Government banned the use of leaded gasoline as recent as in 2008. The results together raise safety concerns and well-being of workers irrespective of nature and characteristics of the work environment. This study included men only in the occupationally exposed group, as auto repair industry in The

Gambia is traditionally dominated by men while women are engaged in other occupations including service and domestic works like cooking and laundry of cloths for the members of the family, providing the potentials making women and children vulnerable to health effects of exposure to Pb especially when the cloths for the entire family are washed together. As this was a pilot study only, limited furthermore by size of studied populations, the findings warrant further investigation; however, the associations found with a common auto repair practices performed on a day-today basis have important clinical and disease prevention implications.

Worksite parameters and substantive lowering of personal hygiene standards have shown in several studies to be associated with elevated BLLs [13, 25, 26]. In addition, behaviors involving hand-to-mouth contact such as smoking and eating while at work may lead to additional exposure via ingestion. Our study data indicates that 43% of the exposed population are either smokers or ex-smokers, and most eat at work. In a worksite setting with a culture of low personal and hand hygiene, these behaviors have a higher propensity to drive the ingestion of Pb in the occupational group. Ahmad et al. found that workers who smoked or did not bath regularly had higher mean blood Pb levels than those who did not smoke or bath regularly [16]. Though a finding from an old data, Decharat et al. and Dykeman et al., also found that smoking, eating at work, and wearing uniforms were significantly associated with higher BLLs among radiator repairs in Mexico and Thailand [29, 30]. Like in this study, Dykeman et al., also used a case-control methodology [30]. It is important to educate the workers on the potentials of the routes of exposure and the need for personal hygiene to reduce exposure to Pb and other related heavy metals in the workplace.

In this study, the proportion of participants with high BLLs was found to be higher among those who repair radiators and batteries, do panel beating, or weld vehicle parts than those who did not perform these activities. In a similar studies on scrap metals workers [31], battery manufacture, repairing automobile radiators [32] and welding fume [33] all found toxic levels of sources of occupational Pb among the auto repairers. Most of these studies were conducted in high income countries like Sweden and Turkey where standard occupational health regulations are instituted and enforced, and the personal hygiene culture is likely higher than the study setting. Therefore, it can be corroborated that some participants in this pilot who performed these activities had BLL of greater than 60ug/dL. It will be interesting to make a follow up study to assess the associated health outcomes for occupations in this industry in The Gambia or other LMICs with similar settings.

A body of scientific evidence suggests that long working hours is associated with increased levels of exposure [4, 16, 20, 34, 35]. In this study, almost all occupationally exposed workers usually worked more than 8 hours per day or greater than 40 hours per week. To the best of our knowledge, little or no study has assessed the association between long working hours and increasing levels of BLLs. By and large, the data has indicated that duration of exposure might have an influence on BLLs among participants. This could have a significant public health implication for workers in the auto repair industry in The Gambia as there are neither national occupational health and safety laws nor administrative procedures to limit the duration of exposures. The industry is poorly regulated as far as occupational safety is concerned. Workers have lengthy workweeks and workdays coupled with inadequate supplies of appropriate PPEs. Public health and regulatory efforts have evidence of success to protect worker exposure levels [36-38]. It's also important that the country prioritizes regulating the importation of goods that may contain Pb as well as enforcing the existing regulations to protect the health of the population. The people who do not have an education do not deserve to risk their health each time they go to work. This is a serious issue that can be fixed if The Gambian government and the citizens begin to take it seriously and grasp the situation at hand. It does not only affect those who are working in settings where Pb is present, but also their families, especially the children, occupationally exposed workers go home after workday and have the propensity to expose children and family their work cloths and other fomites [3, 39].

Limitations of the study

As this was a pilot, the study team didn't collect data to estimate the effects on BLLs of environmental sources including those from the roadway environment. Additionally, the study was conducted in workplaces located in urban Gambia. Thus, our study is population doesn't include occupationally exposed workers in rural Gambia where socioeconomic and educational factors are lower. Despite these limitations, this paper provides essential information that government authorities in The Gambia and collaborators can use to table the need to improve worker health.

Conclusions

This pilot study found elevated BLLs among both the occupationally exposed and unexposed populations like healthcare workers. However, the proportion differs with the participants in the former showing higher BLLs. This implies exposure occurring from multiple sources. Workers who repair radiators and batteries, do panel beating, or weld cars parts have higher BLLs. Auto repair is done primarily in unhygienic workplaces and/or with personal hygiene concerns. These findings have important clinical, disease prevention, and policy implications for the general public but specifically the auto repair industry. Designing prevention strategies including but not limited to occupational health regulations to protect workers, administrative controls or other controls like appropriate PPE education and utilization, and general education on Pb in the workplace is critical. These results add to the growing body of evidence about negative effects of occupations and environmental contamination of Pb to the health of worker populations and the public.

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