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Association between bone lead levels and Aggression in the Birth to Twenty Plus Cohort

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the Degree of **Master of Science in Epidemiology (Epidemiology and Biostatistics)**

14 October 2020

DECLARATION

I ***Nonhlanhla Tlotleng*** declare that this Research Report is my own, unaided work. It is being submitted for the Degree of **MSc Epidemiology** at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



_____ (Signature of candidate)

14th day of October 2020 in Johannesburg

ABSTRACT

Background: Environmental lead exposure has been associated with a number of adverse health outcomes in children including behaviour problems. While the association between blood lead levels and aggression has been investigated in children and adolescent youth in South Africa, there are limited studies that have assessed health outcomes associated with cumulative bone lead levels. Therefore, the aim of this secondary analysis was to assess the association between bone lead levels and aggressive behaviour among the youth in South Africa.

Methods: This study was a secondary analysis from the Birth to Twenty Plus Cohort conducted in Johannesburg-Soweto metropolitan area. In this study, bone lead levels of men and women were measured using K-Shell X-ray Fluorescence (KXRF). The Buss Perry Aggression questionnaire was administered to study participants to measure their aggression behaviour as a score. Data on demographic, socioeconomic factors, and psychosocial factors were obtained using a structured questionnaire. Linear regression models were fitted with continuous bone lead levels as the independent variable and the four scales of aggression adjusting for known study confounders. Furthermore, structural equation modelling (SEM) was used for path analysis to assess direct and indirect pathways in the association between bone lead and aggression.

Results: Overall, there were 100 participants in this study, 53 males and 47 females aged 23 (n=77) and 24 (n=23) year olds. Most of the participants had secondary education (n=61), and a few achieved tertiary education (n=17). The linear regression models showed that bone lead levels were associated with the aggression score for anger (p=0.017), but not associated with physical aggression, verbal aggression and hostility. When the total aggression score was used as the dependent variable there was no association with bone lead levels. Nonetheless, the models showed that as bone lead levels increased there is an increase in the score for aggression. Psychosocial factors such as a history of family violence and

exposure to neighbourhood crime were found to be significant predictors for aggression. Path analysis using SEM showed a significant direct effect between maternal education and bone lead levels ($p<0.001$) were a higher level of maternal education was found to decrease bone lead levels.

Conclusion: This study showed that bone lead levels was associated with aggression score for anger. While a larger sample size may be necessary to further investigate the association between bone lead levels and aggression, the findings from this study provides a preliminary overview in the relationship of these important public health factors. This information may be crucial in the drafting of policies designed to combat crime associated with youth aggression in South Africa.

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ABBREVIATIONS

Pb: Lead

CDC: Centre for Disease Control and Prevention

PVC: Polyvinyl Chloride

BBB: Blood Brain Barrier

BPAQ: Buss Perry Aggression Questionnaire

YSRQ: Youth Self Report Questionnaire

BLLs: Blood Lead Levels

BT20: Birth to Twenty Plus

KXRF: K-Shell X-ray Fluorescence

SD: Standard deviation

IQR: Interquartile range

VIF: Variance Inflation Factor

SEM: Structural Equation Modelling

RMSE: Root mean square error

SRMR: Standardized root mean square

CFI: Comparative fit index

TLI: Tucker Lewis Index

CHAPTER 1
1. BACKGROUND

Exposure to Lead (Pb) remains a major public health concern globally. In Africa, environmental lead is classified as a health hazard contributing to almost one-third of disease burden in Africa (1). In the year 2000, it was estimated that about over a million of the population in the world had blood lead levels more than ≥5µg/dL, which is above the recommended level as specified by the Centre for Diseases Control and Prevention (CDC) (2). Lead has previously been used in petrol, batteries, paint manufacturing, fishing weights, electrical appliances and in road markings (35). The impact of lead poisoning to the public resulted in the phase-out of lead-based products, nonetheless, there remains multiple sources of lead exposure. Environmental pollution, contaminated soil, dust, water and food are sources by which the public become exposed to lead (4). As an example, lead is released into the environment from deteriorating walls, door frames and windows in houses containing leaded paint. In children, lead poisoning occurs through exposure to polyvinyl chloride (PVC) toys and playground equipment painted with lead-based paints (4).

At low exposure levels, lead may cause acute and long term health effects such neurotoxicity which can subsequently affect behaviour and intellectual ability (6). On the contrary, high levels of lead exposure have been found to damage major organs such as kidneys, the liver, reproductive organs, and the cardiovascular system (6). The adverse health effects of lead poisoning are generally irreversible (6). Upon inhalation, lead is transported into the bloodstream and is able to cross the blood brain barrier (BBB) into the brain (4). This may lead to neurotoxicity whereby lead alters neurotransmitters and hormonal systems resulting in brain injury and brain volume reduction (7). Excess lead in the body is then stored in bones. Thus, lead levels in the blood provide a convenient and effective way of measuring acute lead exposure. On the other hand, assessing bone lead levels in the body provides a way of assessing cumulative or lifetime lead exposure. It has been found that approximately 80-95% of lead in the body is stored in the bones (7).

Several studies on environmental lead have reported a significant association between blood lead levels (BLLs) and behavioural problems in young children and youth (8). For example, it has been shown that children that are exposed to lead may have cognitive dysfunctioning, anti-social behaviour, violent and aggressive behaviour (9). In addition, lead was found to predict intellectual functioning of children in early adulthood (9). Needleman et al (1996) also showed that children with high levels of bone lead exhibited violent and aggressive behaviour (10). In addition to these findings, the probability of participating in criminal activities for children exposed to lead were shown to increase (9).

Aggression is a significant risk factor for antisocial behaviour including delinquency and behavior problems (11). Aggression is defined in the literature as a “response which brings a harmful effect to another person” (12-14) and can be measured using validated tools such as the Buss-Perry Aggression Questionnaire (BPAQ) (15) and the Youth Self reporting questionnaire (YSR) (8). The BPAQ consists of 29 items, classified into four categories, namely verbal aggression and physical aggression that “involves hurting or harming others”, hostility aggression which consists of “feeling of ill will and injustice” and have been shown to represent the “cognitive component of behaviour” and anger which “represents the emotional component of behaviour” (15).

In South Africa, many studies have been conducted to describe the association between blood lead exposure and aggressive behaviour (16). While the relationship between lead levels in the blood and aggressive behaviour has been widely studied in the South African young population, the impact of bone lead, which is a biological marker of lifetime lead exposure accumulated in the body, has not been fully explored in late adolescent youth or in early adulthood. This study will, therefore, investigate the association between bone lead levels and aggressive behaviour among the youth in South Africa.

Besides lead exposure, studies have shown that there are other environmental and psycho-social factors that may enhance aggressive behaviour in lead-exposed children (6, 17). Some of these factors are also determinants of lead levels. As an example, poor parenting, family violence and low socioeconomic status have been associated with aggressive behaviour (12). A study assessing BLLs and aggressive behaviour in children 13 years of age showed that low class socioeconomic status increased the risk of lead exposure (18). Children residing in poorly maintained housing previously painted with lead containing paint were therefore at risk of aggressive behaviour (19, 20). There is evidence that behaviour problems due to lead exposure may therefore be reduced by higher socioeconomic status and better social conditions (19).

Adversities in the home environment such as a history of family violence and other social problems have also been considered as risk factors for displaying aggressive behaviour in children (12). Aggressive behaviour appearing in young adults have been attributed to the increased substance abuse, were illegal drug use was found to be connected with escalations in violence and violence-related injuries (12). With this knowledge, the study will further explore psycho-social and environmental factors influencing bone lead levels and aggressive behaviour. A conceptual framework of the causal relationship between lead and aggression and other related influencing factors based on the literature review is shown in Figure I.

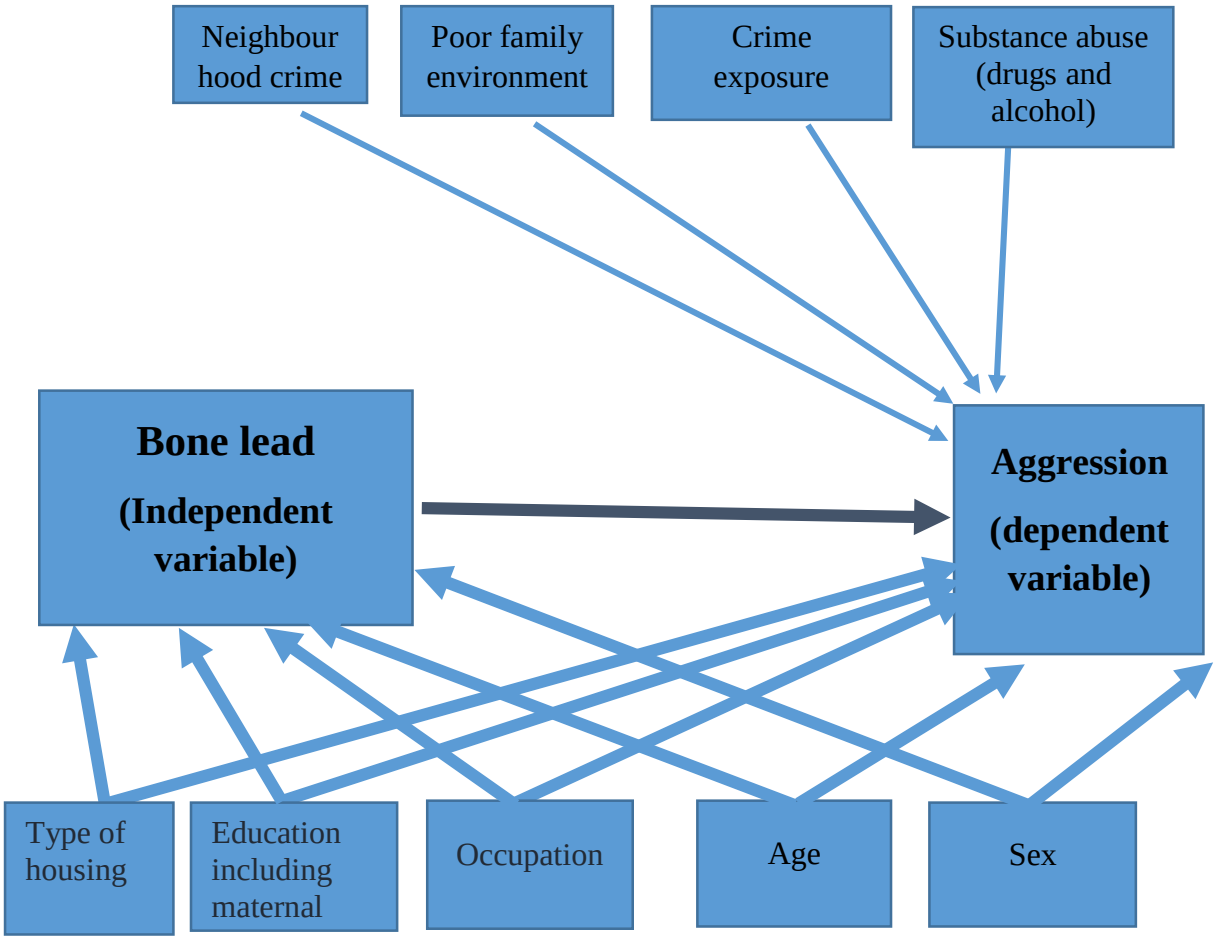


Figure 1. A Conceptual Study Framework showing confounding variables in the pathway between bone lead and aggression. Other risk factors association with aggressive behaviour based on literature.

CHAPTER 2

2. LITERATURE REVIEW

This chapter provides a literature on the historical uses of lead products and its burden of disease in low income countries. Different sources of lead exposure are discussed in detail. Furthermore, adverse health effects following exposure to lead are described, where previous studies assessing the health effects associated with acute and chronic exposure to lead are discussed in detail. The problem statement of the current study and justification for carrying out the study are described, followed by the aim and the objectives of the study.

2.1 Lead and its burden in low to middle income countries

Lead is a blue-grey naturally occurring metal present in all parts of the environment (5). Naturally, lead has properties which make it suitable for a number of diverse applications. For an example, as a result of its low melting point and its resistance to fire, lead has been used in the manufacture of protective equipment such as x-ray shields and fire protection gear (5). In addition, lead is resistant to corrosion and as such has been useful in the manufacture of paint to increase the durability of paint products. Other applications of lead are in the manufacture of electrical equipment, cosmetics, and jewellery (5).

Once released into the environment, lead can remain in the air for extended periods becoming toxic to humans. The general population is usually exposed through inhalation of lead particles in the air and through ingestion of contaminated water and food (21). It was estimated in South Africa that exposure to lead may have caused about 1,428 (0.27%) of all deaths in the year 2000 (22). In the same year, it was estimated that 40% of children globally had lead levels in the blood above 5µg/dl, with the majority (97%) of them living in developing countries (22, 23). It was estimated in 2016 that 13,873,550 of disability adjusted life years (DALYs) was attributable to environmental lead exposure (24). In 2017, the majority of cases of

intellectual disability in children in low to middle income countries were due to environmental lead exposure (21, 23). Nonetheless, the BLLs of the general population in low income countries have been shown to decrease following government prohibitions on leaded petrol and a decrease in lead content in consumer based products such as children's toys and paints (25). However, reports from Sub-Saharan Africa have indicated that the burden of disease due to lead remains a public health concern and that BLLs in the population still remains above the recommended levels (26, 27) despite the phase-out of leaded-petrol in these countries (27). One reason for this continued lead exposure may that lead based products are still available in some consumer products such as cosmetics, cooking pots and herbal remedies. In addition, it has been recognized that lead effects may occur at levels lower than the set exposure levels (25, 28).

2.2. Sources of lead exposure

Environmental pollution is a major source of lead exposure (29). It was estimated that about ninety percent of the lead in the environment is found as fine inhalable particles (22). In the early 80s, leaded petrol was the main source of environmental pollution in South Africa. Lead particles from petrol were released into the environment from vehicle emissions (30). At this time, a survey that was conducted in Johannesburg townships and suburbs to determine the BLLs in children found that lead levels ranged from 6 to 26µg/dL, with a mean lead levels of 11.9µg/dL (31). Results emanating from this research led to the introduction of lead-free petrol in 1996, were in 2006 leaded petrol was completely discontinued (32). Even though the BLLs were decreasing due to the discontinuation of leaded petrol, the burden of disease due to lead exposure still remained an important topic of research in public health.

Currently, it has been estimated that about 75% of the total lead exposure were from household dust contaminated with lead particles from paint, about 23% comes from food and water, and 2% from soil and other sources (29). Montgomery and Mathee (2005) showed a lead paint content ranging from 0.01%-29% in exterior and interiors

surfaces of residential homes that were randomly selected across various suburbs in Johannesburg (33). Contaminated household dust due to the deterioration of walls, door frames and windows painted with lead in residential homes was the main source of lead exposure in toddlers and young adolescent children (34). In poorer communities in South Africa, such as in town ships children became exposed to environmental lead through other mediums such as lead based paint in toys (22) and playground equipment (3). Njati et al (2019) reported lead paint of concentration of up to 145,000 mg/g being removed from children's toys, such as building blocks, obtained from leading toy sellers and other consumer retail chains (4). In addition, a study conducted in Johannesburg showed that 49 public parks with children's playground equipment were painted with lead based paint (3). In the study, majority (96%) of the parks studied contained lead paint, of these paint chipping was evident in 83% of the equipment in the playground (3). Even though lead exposure was historically high in children, the average exposure to lead has now declined by one seventh from what it was in the past three decades (29).

Other sources of lead exposure in the population include exposure from landfill sites (30) and lead mining activities in the informal and formal sectors (35). Consuming contaminated water from leaded pipes is another important source of exposure to population residing in houses were lead containing plumbing pipes and fittings were used (20, 27). In addition, some occupations may expose workers to lead such as lead from mines, car battery manufacturing and repairing, paint and pigment industry, stained-glass makers and weldering (36, 37). The families of those exposed to lead during work related activities are often subjected to secondary exposure when the workers bring their work clothes and work tools home.

2.2 Health effects of lead exposure

Lead poses adverse social, economic and health consequences (20, 27). Upon exposure, lead is primarily taken up into the blood plasma and is distributed to the

blood, soft tissues and in the bone (7, 38, 39). Soft-tissue lead is predominantly found in the kidney, liver, brain and in the lungs (29). In the body, about 90% of lead is stored in the teeth and in the bones (29). Prolonged lead exposure increases the lead concentration in the bone, hence bone lead is a measure of life time lead exposure (17).

Lead affects major organs in the body, primarily the central nervous system (CNS) of the developing brain, as such children are more at risk than adults (40). Lead induced damage in the prefrontal area of the brain can lead to a number of neurological disorders, including mental retardation, Alzheimer's disease, schizophrenia, Parkinson's disease and nerve damage (40). Indeed, epidemiological studies have linked lead exposure not only to changes in behavior, but also to brain structure (19). In a Cincinnati Lead Study (CLS), data were collected from a population of 157 participants of ages between 19 and 24 years old to examine the health effects of low to moderate childhood lead exposure on the adult brain volume (19). The results showed a linear concentration dependent relationship between lead levels and brain volume where higher mean levels of childhood BLLs resulted in a reduction in grey matter volume, specifically in the prefrontal and the anterior cortex of the brain (19). These frontal areas of the brain are thought to be associated with cognitive and emotional behavioral control (41).

The role of lead in the mental development of young children has been recognised (27). In 1943; Byers and Lord reported the negative adverse effects on mental health development in young children who were hospitalized due to lead poisoning (42). The main source of lead exposure in their study was leaded paint (42). Between four and ten years later, these children participated in a follow-up study examining their mental development and the results showed cognitive deficiency; as well as impulsive behavior; and convulsions (42). In subsequent studies, there was strong evidence showing a positive association between childhood lead exposure and lowered IQ levels which have been shown to affect children's academic performance and achievement (9, 43, 44). In addition to the above-mentioned health effects, other adverse outcomes associated with lead exposure includes shortened concentration in school children, increased high blood pressure resulting in cardiac diseases,

gastrointestinal effects, hearing loss, and social behavioral problems including an increased risk of violence and substance abuse (20, 43).

2.3 Lead exposure and aggressive behavior

The Port Pirie Cohort study in Australia was the first to evaluate the association of elevated blood levels and “emotional and behavioral problems” in children (45). In the study, a significant association between behavioral problems including aggressive behaviour and cumulative blood levels was found in boys and girls aged eleven to thirteen years (45). The association between lead levels and aggressive behaviour has also been studied in South African youth with blood lead levels exceeding 10µg/dL (8, 17). These studies reported a significant association between elevated levels of lead in the blood and aggressive behaviour. In the study by Naicker et al. (2012), elevated blood lead levels were associated with some of the aggressive behavior items in the YSR questionnaire in young boys after adjusting for socio-economic factors (8). Similarly, Nkomo et al (2018) reported a higher level of blood lead in adolescent youth aged fourteen to fifteen years and this was significantly associated with direct forms of aggression such as verbal and physical aggression (17).

Following the findings of the association between blood lead and behaviour, studies investigated the association between bone lead and behavioural problems including aggression. For example, a study by Needleman et al (1996) reported a significant association between elevated bone lead levels and aggression in eleven-year-old boys (10). Following this, a subsequent study was conducted to assess the association between bone lead levels and criminal behaviour in the youth (6). In the study, bone lead levels of detained youths that were declared delinquent was higher than those of non-delinquent high school youths, where the odds of delinquent behaviour was shown to be higher in youth with high mean bone levels than those with lower levels of bone lead. The bone lead levels in the exposed group ranged from 11±32.7ppm versus 1.5±32.1ppm in the control group (6).

2.4 Environmental and psychosocial factors associated with lead exposure and aggressive behaviour.

A study that was conducted in South Africa by the Centre for Justice and Crime in 2009 identified some of the key factors that may heighten aggressive behavior in young males and females from similar backgrounds (46). These included psychosocial factors such as history of family violence, exposure to crime and violence, interaction with delinquent peers and substance abuse (12, 46). The situation in the home environment such as children having both parents at home or a single parent can also affect the development of aggressive behaviour (47). It has been shown that children raised in household with single parents may show tendencies of aggressive behaviour compared to those who were raised in households with two parents (12, 47).

Exposure to lead has therefore been exacerbated by the unfavourable impact of social determinants such as poverty, low level of education, poor living conditions and experiences of violent behaviour (6, 48, 49). For example, it has been reported that children from poor households have a higher chance of being exposed to lead than children from middle income or high income families (50). In addition, children from families below the low income brackets usually tend to grow up and live in older buildings with leaded paint or leaded pipes which will increase the odds of elevated BLLs compared to children from high-income families (9). Mindful of these factors, the current study will use the path analysis to quantify and assess the direction of the relationship between explanatory variables (study confounders) and the main independent variable (bone lead) and the dependent variable (aggression).

2.5 Problem Statement

Lead exposure in early childhood is a risk factor for aggression, violence and criminal behaviour. Previous studies conducted in South Africa showed that 35% to 78% of first grade school-children had BLLs above the internationally accepted level of 5µg/dL (51). While the adverse health effect of acute lead exposure has been

assessed in children (≤ 13 years), the association between cumulative bone lead levels and aggressive behaviour in the youth (15-24 years) has yet to be understood.

2.6 Justification for study

Lead exposure increases the risk of developing aggressive behavior later in life (10). As such, children who have been exposed to lead are at a higher risk of delinquent behavior later in life (52). Crime is an important public health problem (11). Studies have indicated that the high crime rates can be due to lead exposure (50). While studies assessing lead exposure and aggressive behaviour and delinquency have focused more on children (≤ 13 years), this study will assess the association between cumulative lead exposure and aggression among the youth (15-24 years). Thus, this study will assess the association between bone lead levels and aggression in the youth as this outcome might persist into adulthood (52, 53). Identifying environmental risk factors that give rise to aggression in children and in the youth will also aid in determining preventable factors associated with aggression. Findings from this study will be provided to the South African Department of Health and all other relevant stake holders – the information may be crucial in the drafting of policies designed to combat crime in South Africa by preventing lead exposure and early interventions to prevent long term effects.

RESEARCH QUESTION

Is there an association between bone lead levels and aggressive behavior among the youth (23 and 24 years old), males and females within the Birth to Twenty Plus Cohort (BT20) in South Africa?

STUDY AIM AND OBJECTIVES

Aim of the study

The study seeks to investigate the association between bone lead levels and aggression among males and females in Johannesburg, South Africa.

Objectives of the study

1. To describe the psychosocial and demographic characteristics of the study participants.
2. To determine the association between bone lead levels and aggression after adjusting for individual level confounders.
3. To assess direct and indirect pathways in the relationship between bone lead and aggression.

CHAPTER 3
3. METHODS

In this chapter the design of the of the present study is described. The study population and the setting of the primary study from which this secondary analysis is based on are also described. The chapter further defines the independent and dependent variables in the current study as well as study confounders and further discusses how they were assessed and measured. Lastly, the data management plan and the statistical tests used in the analysis for each objective are discussed.

3.1. Study description

3.1.1. Study design

This study was a secondary data analysis of a sub-sample from the BT20 plus cohort. This secondary analysis adopted the design of a cross sectional study as it assessed bone lead levels and aggression among the youth at one point in time.

3.1.2. Study setting/site

The BT20 plus cohort was established in South Africa in the 1990s with the aim of conducting longitudinal studies to assess the health of children in the Johannesburg area (54). The cohort study was conducted at Chris Hani Baragwaneth Hospital in the South Western township of Johannesburg. The primary study enrolled women in their second and third trimester of pregnancy from major public health facilities. Singleton children (n=3273) born between April and June 1990 who were resident of Soweto-Johannesburg were enrolled into the birth cohort and were followed from birth to their early twenties (55). The entry criterion into the study included that the mother and baby remain in the Soweto-Johannesburg area until the child was at least six months old. During the years that the cohort has been conducted, a low attrition rate of less than 3% was reported annually. Attrition rate in the two decades of the cohort has been relatively low (30%), with most occurring in infancy and early childhood. To date there are about two thousand three hundred children and families participating in the study (56).

3.1.3. Study population

The population in the study are the youth (23 and 24 years) males and females from the BT20 plus cohort in Johannesburg, South Africa.

3.1.4. Exposure, outcome and potential confounders of the study

3.1.4.1. Bone Lead Levels

Bone lead levels were the exposure variable in this study. Tibial bone lead concentration levels in the study participants were estimated using a non-invasive technique K-shell X-ray fluorescence (KXRF). The KXRF technique has been used as a biomarker to assess cumulative lead exposure levels (57). To measure the levels of bone lead, the tibia bone of the study participant was exposed to X-ray fluorescence for 30 minutes. The XRF uses a small radioactive material called 109Cd which emits 88.035 *keV* photons, measured with a backscatter counting geometry. The photons are used to fluoresce the atoms of the tibial bone being measured. During this process, photons that are generated are collected and counted and the results are graphically presented in a computer screen connected to the XRF. The limit of detection for the KXRF bone lead measurement is reported as10ppm (58).

3.1.4.2. Measurement of Aggression

Aggression was the outcome variable in the study. The BPAQ was administered to study participants to measure aggression as a score (15). The BPAQ is a validated tool that have been used in studies in low to middle income countries (59, 60). The questionnaire consists of twenty-nine items which measures four components of aggression. For the analysis, the items were first divided into the four components of aggression, that is physical and verbal aggression, hostility and anger. For the analysis, the score for each of the four items were created. Physical aggression consisted of nine questions and the scoring from this item ranged from 18 to 38. Verbal aggression had 5 items with the scoring ranging from 10 to 25. Anger,

consisted of 7 items with a scoring range of 14 to 35 and hostility consisted of 8 items with scoring range of 10 to 37 (15). The higher the score the more aggressive the participants. The total aggression scores of the twenty-nine items were also created and this was also used in the analysis. The level of aggression in the questionnaire was rated on a five-point Likert scale, presented as 1 (extremely uncharacteristic of me), 2 (somewhat uncharacteristic of me), 3 (neither uncharacteristic nor characteristic of me), 4 (somewhat characteristic of me) and 5 (extremely characteristic of me).

A Cronbach's α reliability coefficient was used to determine the reliability of the items. An alpha coefficient of 0.7198 was obtained for the nine items of physical aggression, 0.6684 for the seven items of anger, 0.7150 for the eight items of hostility and 0.5640 for the five items of verbal aggression, indicating acceptable reliability among the items. The 29 items reported a scale reliability coefficient of 0.8364 similar to that reported previously (15, 60).

3.1.4.3. Study confounders

A separate questionnaire was administered to the study participants to obtain information on demographic, socio-economic factors, and psychosocial factors. A confounding variable in the study was defined as a variable which is a risk factor for aggression and is associated with bone lead levels, but not a consequence of bone lead levels.

The following variables were therefore considered as study confounders and potential predictors of aggression: age, sex, level of schooling (categorized into three: Grade 5 or less, grade 6-12 and tertiary education), presence of both parents at home, home environment, neighbourhood crime; profile of illegal substance abuse (use of drugs such as dagga and glue), use of alcohol and socio-economic factors (maternal education, type of housing and occupation status).

Information on the participant's home environment (referred to as history of family violence in this analysis) was obtained by asking the participants to respond to the following statements "We argue a lot in our family, "people in my family hardly ever lose their temper and "people in my family sometimes hit each other when they angry" were the participant will have to agree or respond as a "Yes" (coded as 1) and disagree or respond as a "No" (coded as 2). To obtain information on neighbourhood factors, the participants were asked how they generally feel in their neighbourhood with a "feeling of somewhat safe or very unsafe" coded as 1, and "somewhat safe or very safe" coded as 2. Questions on whether the participants have personally experienced crime and violence in the neighbourhood were asked as "ever in your life experience any crime" with "Yes" coded as 1 and "No" coded as 2. Socioeconomic status was measured by considering maternal level of education (which was categorized into four levels, i.e. no formal education, primary schooling, secondary schooling and post school education), type of housing (which included formal housing such as free standing house, townhouse or hostel and informal housing (shack, squat and any other informal room housing) and participants level of education and occupational status as proxies.

3.2. Ethical consideration

Ethical approval for the primary study was acquired from the University of the Witwatersrand Human ethics research committee. Ethics clearance for this secondary study was obtained from Human Research Ethics committee (HREC), Faculty of Health Science, University of the Witwatersrand, Johannesburg. Clearance certificate number **M 191116**.

3.3. Statistical Analysis

3.3.1. Data management

All data cleaning and analysis was done using Stata version 15. The data was checked for duplicates and missing values.

Analysis to address the objectives

Objective one

A description of psychosocial and demographic characteristics of the study participants was illustrated. The categorical variables were presented as frequencies and proportions. Data were stratified by sex. Pearson chi-squared test were used to assess the association between categorical variables.

Continuous variables in the study were bone lead levels and the four aggression scores (physical, verbal, anger and hostility). The distribution of the continuous variables was checked for normality. Bone lead levels were summarized as means ± SD and medians, 25 and 75 Interquartile ranges (IQR). For continuous variables that were normally distributed, an independent student *t-test* was conducted to test for the difference in means. Testing was set at the 0.05 level of significance. The geometric mean, mean and ranges for the aggression scales were described and a student *t-test* was conducted to test for the differences in means, stratified by sex.

Objective two

To assess the association between bone lead levels and aggression a linear regression model was fitted. Separate models were fitted with physical aggression, verbal aggression, anger, hostility and total aggression score as outcome variables. In the univariate analysis, a simple linear regression was fitted with each aggression scale as an outcome variable and bone lead levels as the main explanatory variable. In addition, a simple linear regression between each study confounders and each aggression scale was fitted and these results.

A backward elimination using a liberal p-value of 0.20 was used to include variables in the multivariable model. Age and sex were automatically kept in all multivariable models as study confounders. A model-building strategy using maximum likelihood ratio tests was used to reach a final model, where variables with p values ≤0.05 were retained in the final model. Variables with p ≤0.001 were reported as being highly

significant, those with p ≤0.08 were reported as being marginally significant and were also retained in the final model. A model with interaction terms between the independent variables was also fitted. Goodness of fit was assessed using regression diagnostics were residuals were used to check the assumptions of linearity, normality and constant variance to reflect the adequacy of the final models. Once the final models were fitted, a multi-collinearity test was conducted using variance inflation factor (VIF), where a VIF of ≥ 10 indicated multi-collinearity.

Objective three

To further quantify and assess the direction of the relationship between bone lead and aggression, structural equation modelling (SEM) was fitted. A simple SEM model was fitted with bone lead as the independent variable and aggression as the dependent variable (Model I). In the model, aggression was the latent variable which as previously indicated was assessed by four observed variables: Physical aggression, verbal aggression, hostility and anger. All observed variables were denoted by rectangular boxes and latent variables (unobserved) were denoted in ovals. Model II was fitted to determine direct and indirect effect of study predictors on aggression as an outcome viable. In the model, pathways between educational level, age, sex, type of housing, occupational status and maternal education were created as these variables were identified as determinants of bone lead levels (61). These created indirect pathways to aggression via continuous bone lead levels. Direct predictors for aggression in model II were a history of family violence, exposure to crime, growing up with a single parent and use of drugs and alcohol. To assess model fit, SEM fit indices including the root mean square error (RMSE), standardized root mean square residual (SRMR), comparative fit index (CFI) and Tucker Lewis index (TLI) were used. A RMSE below 0.05, P-close greater than 0.05, SRMR greater than 0.08, CFI and TLI value of 0.95 and above indicated a good fitting model (62). Where necessary, the model was checked for improvement using modification of indices.

CHAPTER 4
4. RESULTS

In this chapter we present the findings from the analysis based on the objectives of the study as presented in chapter 2. The chapter will first provide the background of the study participants by presenting the analysis of the demographic and psychosocial characteristics. This is followed by a tabulated summary of the measured bone lead levels and aggression scores stratified by sex. The findings of the univariate and multivariable models for objective 2 are presented in tabular forms. Finally, the SEM diagrams are presented.

Objective 1

The results of the socio-demographic and psychosocial characteristics of the study population stratified by sex are shown in **Table 1**. Overall, the study consisted of 53 males and 47 female participants. The population had two age categories, which were divided into two groups, 23 years and 24 year olds. Majority of the study participants (n=77) were in the 23-year age group. About 60% of the study participants reported not growing up with both parents, with 58.7% (n=27) being females and 62.3% (n=33) being males. Most of the study participants had secondary level education, with 60.4% (n=32) being males and 61.7% (n=29) being females and only a few had tertiary/post school education. For maternal education, a large proportion of participants (78%) reported their mothers as having secondary level education.

Socio-economic status was described using proxies such as type of housing and occupational status. For this, the majority of participants, 97.9 % (n=46) females and 96.2 % (n=51) males reported living in formal housing, with only 3% living in an informal dwelling such as a shack. Many of the participants were employed on a casual/ part time basis or self-employed (52%). Experiences in the home environment was obtained by asking whether there was violence or aggressive behaviour in the family and most (67%) disagreed to the statement. On the contrary,

many of the participants reported a feeling of being unsafe or somewhat unsafe in their neighbourhood, with 84.9 % (n= 45) being males and 74.5% (n=35) being females. The use of alcohol and drugs was more prevalent in males than in females, with 100% of males (n=53) reporting alcohol use and 75.5% (n=40) males reporting illicit use of drugs such as hallucinogens, cannabis, cocaine, inhalants and opiates among others. A chi-square test showed the use of drugs and alcohol to be significantly different between males and females (*p <0.001*).

Table 1: Description of socio-demographic and psychosocial characteristics of study participants by sex

Variable	**Male (n, %)(n=53)**	**Female (n, %)(n=47)**	**Total (n=100)**
Socio-demographic factors			
Age			
=23	41 (77.4)	36 (76.6)	77 (77.0)
=24	12 (22.6)	11 (23.4)	23 (23.0)
Grew up with both parents (missing n=1)			
Yes	20 (37.7)	19 (41.3)	39 (39.4)
No	33 (62.3)	27 (58.7)	60 (60.6)
Level of education			
Grade 5 or less	14 (26.4)	8 (17.0)	22 (22.0)
Grade 6-12	32 (60.4)	29 (61.7)	61 (61.0)
Tertiary	7 (13.2)	10 (21.3)	17 (17.0)
Maternal education			
No formal education	0	1 (2.1)	1 (1.0)
Primary	5 (9.4)	6 (12.8)	11 (11.0)
Secondary	42 (79.3)	36 (76.6)	78 (78.0)
Post school training	6 (11.3)	4 (8.5)	10 (10.0)
Socioeconomic factors			
Type of Housing			
Formal housing (RDP/hostel/ Free standing)	51 (96.2)	46 (97.9)	97 (97.0)
Informal (shack)	2 (3.8)	1 (2.1)	3 (3.0)
Occupation			
Employed, full time	19 (35.9)	18 (38.3)	37 (37.0)
Casual/part time/ self employed	28 (52.8)	24 (51.1)	52 (52.0)
Never been employed	6 (11.3)	5 (10.6)	11 (11.0)
Home and neighbourhood			
Exposure to family violence			
Yes	19 (35.9)	14 (29.8)	33 (33.0)
No	34 (64.1)	33 (70.2)	67 (67.0)

Attitude toward neighbourhood			
somewhat unsafe/very unsafe	45 (84.9)	35 (74.5)	80 (80.0)
Somewhat safe/very safe	8 (15.1)	12 (25.5)	20 (20.0)
Exposure to crime and violence in neighbourhood			
Yes	25 (47.2)	19 (40.4)	44 (44.0)
No	28 (52.8)	28 (59.6)	56 (56.0)
Substance abuse			
Drugs			
Yes	40 (75.5)	6 (12.8)	54 (54.0)
No	13 (24.5)	41 (87.2)	46 (46.0)
Alcohol			
Yes	53 (100)	42 (89.4)	95 (95.0)
No	0	5 (10.6)	5 (5.0)

The distribution of bone lead levels is summarized in **Table 2**. Females showed a higher level of bone lead compared to males, though this difference was not statistically significant. The lowest range in males was 5 ppm and the highest level of bone lead was 11 ppm. In females, the lowest was 4 ppm and the highest was 14 ppm.

Table 2: Distribution of bone lead levels by sex

Continuous bone lead levels (ppm)	**Male n=53**	**Female N=47**	**Total N=100**	**P value***
Mean (SD)	8.09 ±4.42	9.44 ±6.07	8.73± 5.27	0.2021
Range				
Smallest	0	0	0	
Median (IQR)	8 (5-11)	10 (4-14)	9 (5-12.5)	
Largest	18	21	21	

**Student t-test used to obtain p value*

The geometric mean, median and ranges of the four scales of aggression stratified by sex are shown in **Table 3.** As previously indicated, the higher the score the more the aggressive behaviour. Males reported a higher mean score for physical aggression (27.2 and a geometric mean of 26.7), even though the ranges for females was higher (18-38). Females scored higher with items for anger, hostility and verbal

aggression. In addition, the total score for aggression was higher in females (93.81) than in males (91.17). Nonetheless, the *t-test* showed that the total aggression score between males and females was not statistically different.

Table 3: Geometric mean, median and range of aggression scores by sex

	Male (n=53)			**Female (n=47)**			***p* value ***
Variable	**Geometric mean**	**Mean (SD)**	**Range**	**Geometric mean**	**Mean (SD)**	**Range**	
Physical aggression	26.74	27.17 (4.73)	18-36	25.99	26.47 (5.12)	18-38	0.4782
Anger	20.45	20.91 (4.37)	14-32	21.68	22.28 (5.34)	14-35	0.1615
Hostility	24.87	25.68 (6.22)	10-38	25.75	26.47 (5.94)	14-37	0.5193
Verbal aggression	17.00	17.42 (3.76)	10-25	18.22	18.60 (3.70)	10-25	0.1180
Total score	90.03	91.17 (14.28)	57-118	92.55	93.81 (15.44)	66-127	0.3768

**student t-test used to obtain p value*

Objective 2:

Table 4 shows the results of the univariate analysis assessing the association between physical aggression and bone lead and also physical aggression with other risk factors. In the analysis, bone lead was not found to be associated with physical aggression. A history of family violence was found to be significantly associated with physical aggression, violence in the family increased the mean score for physical aggression by 2.6. Participant occupational status was found to be marginally associated with physical aggression.

Table 4: Assessment of the association between physical aggression, bone lead and individual level confounders: Univariate model

Factors	**mean**	**P value**	**95% CI**	
Pb	0.017	0.857	-0.170	0.203
Age				
=23 years	1.00 (ref)			

=24 years	-0.922	0.432	-3.240	1.397
Sex				
Male	ref			
Female	-0.702	0.478	-2.658	1.254
Grew up with both parents				
Yes	ref			
No	0.926	0.363	-1.086	2.937
Education level				
Grade 5 or less	2.618	0.099	-0.505	5.740
Grade 6-12	2.265	0.093	-0.387	4.917
Tertiary	ref			
Maternal education				
No formal education	0.436	0.931	-9.459	10.331
Primary	1.163	0.468	-2.003	4.329
Secondary	ref			
Post school training	1.436	0.390	-1.866	4.738
Type of housing				
Formal	ref			
Informal	4.289	0.137	-1.384	9.961
Occupation				
Employed	ref			
Casual	1.985	0.058*	-0.072	4.042
Unemployed	-1.009	0.543	-4.294	2.274
Exposure to family violence				
Yes	2.591	0.012**	0.575	4.606
No	ref			
Attitude toward neighbourhood				
somewhat unsafe/very unsafe	-1.825	0.138	-4.244	0.594
Somewhat safe/very safe	ref			
Exposure to crime and violence (neighbourhood)				
Yes	-1.094	0.270	-3.053	0.865
No	ref			
Drug use				
Yes	-0.337	0.734	-2.299	1.626
No	ref			
Alcohol use				
Yes	0.8	0.724	-3.688	5.288
No	ref			

After backwards elimination, the final model showed that bone lead was not associated with physical aggression (**Table 5).** However, a positive coefficient indicated that a unit (1 ppm) increase in bone lead level increased physical aggression score by 0.08. Previous history of family violence and being exposed to crime and violence in the neighbourhood were significant predictors for physical aggression. For these, the more the participant is exposed to family violence, their physical aggression score increases by 2.7. A negative coefficient was obtained for neighbourhood factors, that is exposure to violence and crime in the neighbourhood which were also marginally associated with physical aggression. Age and sex as previously indicated were retained in the final model as main confounders for aggression and bone lead. The model shows that as age increases, physical aggression score will decrease by 1.4, though this was not statistically significant. In addition, the mean physical aggression score will decrease for females by 0.99.

Table 5: Assessment of the association between physical aggression, bone lead and individual level confounders: Final model

Factors	**Mean**	**P value**	**95% CI**	
Pb	0.087	0.352	-0.099	0.274
Age				
=23 years	ref			
=24 years	-1.447	0.218	-3.763	0.867
Sex				
Male	ref			
Female	-0.999	0.305	-2.922	0.924
Exposure to family violence				
Yes	2.678	0.012**	0.606	4.750
No	ref			
Exposure to crime and violence				
Yes	-1.873	0.061*	-3.834	0.086
No	ref			

P< 0.05 significant *p ≤0.08 marginally significant

Table 6 shows results of the univariate analysis of anger and bone lead levels as well as anger and other study predictors. Similar to physical aggression, an increase in the level of bone lead increases the aggressive score for anger by 0.108. Factors such as maternal education, being exposed to family violence and a feeling of being unsafe in the neighbourhood were significantly associated with anger. Contrary to

physical aggression, univariate analysis showed that the mean aggression score for anger in females will increase by 1.37 compared to males.

Table 6: Assessment of the association between anger, bone lead and individual level confounders: univariate model

Factors	**Mean**	**P value**	**95% CI**	
Pb	0.108	0.246	-0.076	0.292
Age				
=23 years	ref			
=24 years	-0.263	0.822	-2.572	2.047
Sex				
Male	ref			
Female	1.371	0.162	-0.558	3.299
Grew up with both parents				
Yes	ref			
No	-0.374	0.701	-2.304	1.555
Education level				
Grade 5 or less	2.27	0.157	-0.875	5.329
Grade 6-12	0.098	0.941	-2.537	2.733
Tertiary	ref			
Maternal education				
No formal education	9.756	0.047**	0.147	19.366
Primary	2.029	0.193	-1.046	5.104
Secondary	ref			
Post school training	-0.144	0.929	-3.351	3.063
Type of housing				
Formal	ref			
Informal	1.838	0.523	-3.850	7.527
Occupation				
Employed	ref			
Casual	1.821	0.084	-0.249	3.891
Unemployed	1.059	0.526	-2.246	4.364
Exposure to family violence				
Yes	4.335	<0.001***	2.459	6.212
No	ref			
Attitude toward neighbourhood				
somewhat unsafe/very unsafe	-2.625	0.031**	-4.998	-0.252
Somewhat safe/very safe	ref			
Exposure to crime and violence(neighbourhood)				

Yes	-0.900	0.362	-2.851	1.049
No	ref			
Drug use				
Yes	0.415	0.674	-1.535	2.364
No	ref			
Alcohol use				
Yes	-0.158	0.944	-4.620	4.303
No	ref			

******p<0.001 highly significant; **P< 0.05 significant *p ≤0.08 marginally significant***

In the final model (**Table 7**), bone lead was found to be associated with anger, where a unit increase in bone lead levels increases the aggression score for anger by 0.197. Other factors that were significantly associated with anger were a history of family violence, and feeling of unsafe in the neighbourhood. Being exposed to family violence increases the aggression score for anger by 4.83, however the model showed that "feeling unsafe" in the neighbourhood decreases the score for anger. Previous exposure to crime was found to be marginally significant indicating that it may be associated with anger and was thus retained in the final model.

Table 7: Assessment of the association between anger, bone lead and individual level confounders: Final model

Factors	**Mean**	**P value**	**95% CI**	
Pb	0.204	0.017**	0.038	0.370
Age				
=23 years	ref			
=24 years	-0.560	0.593	-2.632	1.512
Sex				
Male	ref			
Female	1.044	0.231	-0.676	2.765
Exposure to family violence				
Yes	4.836	<0.001***	2.982	6.691
No	ref			
Attitude toward neighbourhood				
somewhat unsafe/very unsafe	-2.275	0.041**	-4.461	-0.089
Somewhat safe/very safe	ref			

Exposure to crime and violence (neighbourhood)				
Yes	-1.629	0.068*	-3.383	0.125
No	ref			

******p<0.001 highly significant; **P< 0.05 significant *p ≤0.08 marginally significant***

For verbal aggression, the univariate analysis showed that maternal education (i.e. no formal education) and a history of family violence were risk factors for verbal aggression. Attitude towards the neighbourhood was also significantly associated with verbal aggression in the univariate model (**Table 8**). Similar to physical aggression and anger, a unit increase in bone lead levels increased the score for verbal aggression score by 0.05. Also, a positive coefficient for verbal aggression score was obtained for females indicating that verbal aggression score increases when you are a female by 1.81.

Table 8: Assessment of the association between verbal aggression, bone lead and individual level confounders: univariate model

Factors	**Mean**	**P value**	**95% CI**	
Pb	0.056	0.441	-0.087	0.198
Age				
=23 years	ref			
=24 years	0.265	0.769	-1.512	2.048
Sex				
Male	ref			
Female	1.181	0.118	-0.305	2.666
Grew up with both parents				
Yes	ref			
No	-0.659	0.400	-2.205	0.887
Education level				
Grade 5 or less	0.195	0.874	-2.242	2.632
Grade 6-12	-0.023	0.982	-2.093	2.046
Tertiary	ref			
Maternal education				
No formal education	7.167	0.061*	-0.327	14.661
Primary	0.439	0.717	-1.959	2.838
Secondary	ref			
Post school training	0.167	0.895	-2.335	2.668
Type of housing				
Formal	ref			
Informal	0.718	0.747	-3.681	5.117

Occupation				
Employed	ref			
Casual	0.647	0.426	-0.958	2.252
Unemployed	-1.120	0.388	-0.368	1.442
Exposure to family violence				
Yes	1.447	0.071*	-0.123	3.017
No	ref			
Attitude toward neighbourhood				
somewhat unsafe/very unsafe	-3.034	0.001***	-4.813	-1.262
Somewhat safe/very safe	ref			
Exposure to crime and violence (neighbourhood)				
Yes	-0.312	0.683	-1.823	1.199
No	ref			
Drug use				
Yes	-0.096	0.900	-1.602	1.411
No	ref			
Alcohol use				
Yes	-2.916	0.091	-6.311	0.479
No	ref			

******p<0.001 highly significant; **P< 0.05- significant *p ≤0.08 marginally significant***

In the Final model (**Table 9**), bone lead was not associated with verbal aggression. However, a positive coefficient indicated that an increase in bone lead increases verbal aggression score by 0.09, and this was found to not be significant. A positive coefficient was found for age, indicating that as the participants age increases, the score for verbal aggression will increase by 0.035. Other factors that remained in the final model as significant predictors of verbal aggression were being exposed to family violence *(p< 0.08*) and attitude toward neighbourhood (*p< 0.05*). The model showed that a history of family violence increases the aggression score for verbal aggression by 1.44, however a feeling of being unsafe in the neighbourhood decreased the score for verbal aggression.

Table 9: Assessment of the association between verbal aggression, bone lead and individual level confounders: Final model

Factors	Mean	P value	95% CI	
Pb	0.093	0.189	-0.046	0.233
Age				
=23 years	ref			
=24 years	0.035	0.967	-1.665	1.735
Sex				
Male	ref			
Female	0.851	0.244	-0.588	2.290
Exposure to family violence				
Yes	1.435	0.069*	-0.116	2.987
No	ref			
Attitude toward neighbourhood				
somewhat unsafe/very unsafe	-2.787	0.003**	-4.603	-0.971
Somewhat safe/very safe	ref			

******p<0.001 highly significant; **P< 0.05 significant; *p ≤0.08 marginally significant***

The univariate model for hostility is shown in **Table 10**. A negative coefficient for bone lead level indicated that an increase in bone lead decreased the score for hostility by 0.02. Factors that were found to be significant in the univariate analysis were history of family violence and “feeling unsafe” in the neighbourhood.

Table 10: Assessment of the association between hostility, bone lead and individual level confounders: univariate model

Factors	Mean	P value	95% CI	
Pb	-0.022	0.848	-0.253	0.208
Age				
=23 years	ref			
=24 years	-2.549	0.077**	-5.380	0.281
Sex				
Male	ref			
Female	0.789	0.519	-1.631	3.209
Grew up with both parents				
Yes	ref			
No	0.972	0.441	-1.524	3.467
Education level				
Grade 5 or less	1.166	0.557	-2.757	5.088
Grade 6-12	0.529	0.753	-2.802	3.860

Tertiary	ref			
Maternal education				
No formal education	2.846	0.647	-9.439	15.132
Primary	-0.517	0.794	-4.449	3.414
Secondary	ref			
Post school training	-0.754	0.716	-4.854	3.347
Type of housing				
Formal	ref			
Informal	3.384	0.344	-3.679	10.449
Occupation				
Employed	ref			
Casual	1.715	0.193	-0.879	4.309
Unemployed	0.946	0.651	-3.197	5.088
Exposure to family violence				
Yes	3.181	0.013**	0.688	5.676
No	ref			
Attitude toward neighbourhood				
somewhat unsafe/very unsafe	-3.750	0.013**	-6.682	-0.818
Somewhat safe/very safe	ref			
Exposure to crime and violence (neighbourhood)				
Yes	0.195	0.874	-2.243	2.633
No	ref			
Drug use				
Yes	0.535	0.662	-1.891	2.962
No	ref			
Alcohol use				
Yes	-0.263	0.925	-5.817	5.291
No	ref			

P< 0.05 significant.

In the final model, bone lead was not associated with hostility, however the model showed that as bone lead increases the score for hostility increases by 0.03. Age, family violence and attitude toward neighbourhood was found to be significantly associated with aggression score for hostility (**Table 11**). The model showed that as age increases, the aggression score for hostility will decrease by 2.93. Other study variables that were associated with hostility was being exposed to family violence and attitude toward neighbourhood where the more the family argues and fights, the aggression score for hostility will tend to increase.

Table 11: Assessment of the association between hostility, bone lead and individual level confounders: Final model

Factors	mean	P value	95% CI	
Pb	0.030	0.792	-0.196	0.256
Age				
=23 years	ref			
=24 years	-2.929	0.037**	-5.675	-0.183
Sex				
Male	ref			
Female	0.553	0.638	-1.772	2.878
Exposure to family violence				
Yes	2.813	0.028**	0.307	5.319
No	ref			
Attitude toward neighbourhood				
somewhat unsafe/very unsafe	-3.712	0.014**	-6.646	-0.778
Somewhat safe/very safe	ref			

P< 0.05 significant.

A univariate analysis between total aggression score and bone lead as well as aggression score and study predictors was fitted (**Table 12**). The models indicated that there was no association between the total aggression score and bone lead levels. However, a unit increase in bone lead levels increased aggressive behaviour. When males were used as a reference, the model showed that the aggression score will increase by 2.36 for females. Though sex was not significantly associated with the total aggression score. The model shows that being employed on a casual/ part time basis or self-employment will increase the total aggression score compared to when being employed full time. History of family violence and attitude towards the neighbourhood were significantly associated with the total aggression score. The coefficient showing the relationship between the independent variables and the dependent variables showed that sex, and socio-economic factors such as informal housing, education, maternal education resulted in an increase in the aggression score.

Table 12: Assessment of the association between total aggression score, bone lead and individual level confounders: univariate model

Factors	mean	P value	95% CI	
Pb	0.158	0.578	-0.404	0.720
Age				
=23 years	ref			
=24 years	-3.469	0.327	-10.457	3.520
Sex				
Male	ref			
Female	2.639	0.377	-3.259	8.539
Grew up with both parents				
Yes	ref			
No	0.864	0.779	-5.225	6.954
Education level				
Grade 5 or less	6.206	0.198	-3.305	15.716
Grade 6-12	2.869	0.482	-5.207	10.947
Tertiary	ref			
Maternal education				
No formal education	20.205	0.180	-9.520	49.930
Primary	3.114	0.517	-6.398	12.627
Secondary	ref			
Post school training	0.705	0.888	-9.216	10.626
Type of housing				
Formal	ref			
Informal	10.230	0.241	-6.973	27.434
Occupation				
Employed	ref			
Casual	6.168	0.053*	-0.079	12.416
Unemployed	-0.125	0.980	-10.101	9.850
Exposure to family violence				
Yes	11.554	<0.001***	5.711	17.398
No	ref			
Attitude toward neighbourhood				
somewhat unsafe/very unsafe	-11.237	0.002**	-18.275	-4.200
Somewhat safe/very safe	ref			
Exposure to crime and violence (neighbourhood)				
Yes	-2.112	0.482	-8.051	3.827
No	ref			
Drug use				
Yes	0.518	0.863	-5.412	6.447
No	ref			

Alcohol use				
Yes	-2.57	0.711	-16.088	11.015
No	ref			

******p<0.001 highly significant; **P< 0.05- significant; *p ≤0.08 marginally significant***

In the final model (**Table 13**), bone lead was not associated with the total aggression score. Exposure to family violence and attitude toward neighbourhood were significant predictors for aggressive behaviour. The more the person is exposed to family violence, their aggression score will increase by 11.9.

Table 13: Assessment of the association between total aggression score, bone lead and individual level confounders: Final model

Factors	**mean**	**P value**	**95% CI**	
Pb	0.419	0.108	-0.942	0.934
Age				
=23 years	ref			
=24 years	-5.312	0.103	-11.709	1.086
Sex				
Male	ref			
Female	1.314	0.624	-3.999	6.627
Exposure to family violence				
Yes	11.906	<0.001***	6.180	17.632
No	ref			
Attitude toward neighbourhood				
somewhat unsafe/very unsafe	-11.229	0.001**	-17.979	-4.481
Somewhat safe/very safe	ref			

******p<0.001 highly significant; **P< 0.05- significant***

Objective 3

A SEM diagram showing a direct pathway between bone lead and total aggression score is shown in Figure 2. Similar to the linear regression analysis, the path coefficient between bone lead levels and aggression was positive, indicating that an

increase in bone lead levels increases the score for aggression. The fit statistic of this model is also shown.

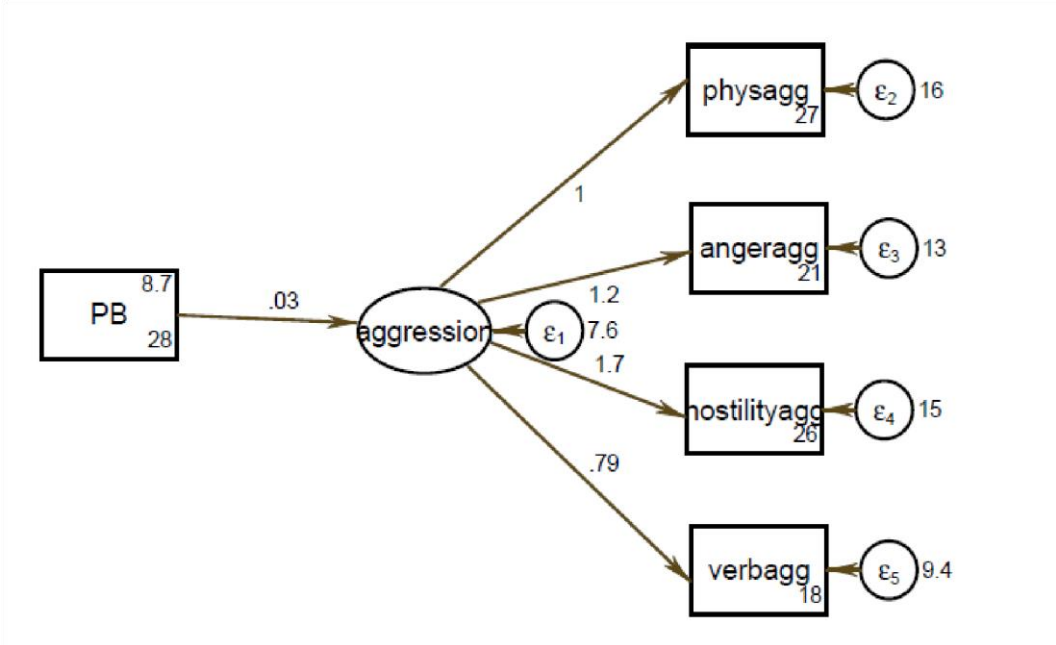


Figure 2: Direct pathway between bone lead and aggression. Path coefficient reflecting the effect of bone lead on aggression is shown (path coefficient 0.03) (*fit statistics: X^2 (model vs saturated) = 4.127 (0.531); RMSE= 0.000 (pclose 0.660); CFI=1.000; TLI=1.022; SRMR= 0.035).*

Model II in Figure 3 shows SEM with direct and indirect pathways between bone lead and aggression and between bone lead and variables considered to be determinants of lead levels. The magnitude of each variable on bone lead and aggression is indicated by the path coefficients The indirect pathways to aggression shows the effect of socioeconomic status predictors (education, maternal education, and employment status) and demographics (age, sex) on bone lead levels (*light khaki arrows*). Similar to the linear regression analysis, a positive path coefficient between bone lead levels and aggression (0.082) was obtained in a direct pathway (*red arrow*), however this pathway was found to not be statistically significant (*p=0.183*). Pathways to other predictors of aggression are shown (*light brown*). The pathway from maternal education to bone lead was found to be significant (*p<0.001*). The path coefficients between age, maternal education and bone lead showed negative

coefficients. The pathway between history of family violence and aggression was found to be significantly associated with aggression (*p<0.001*)

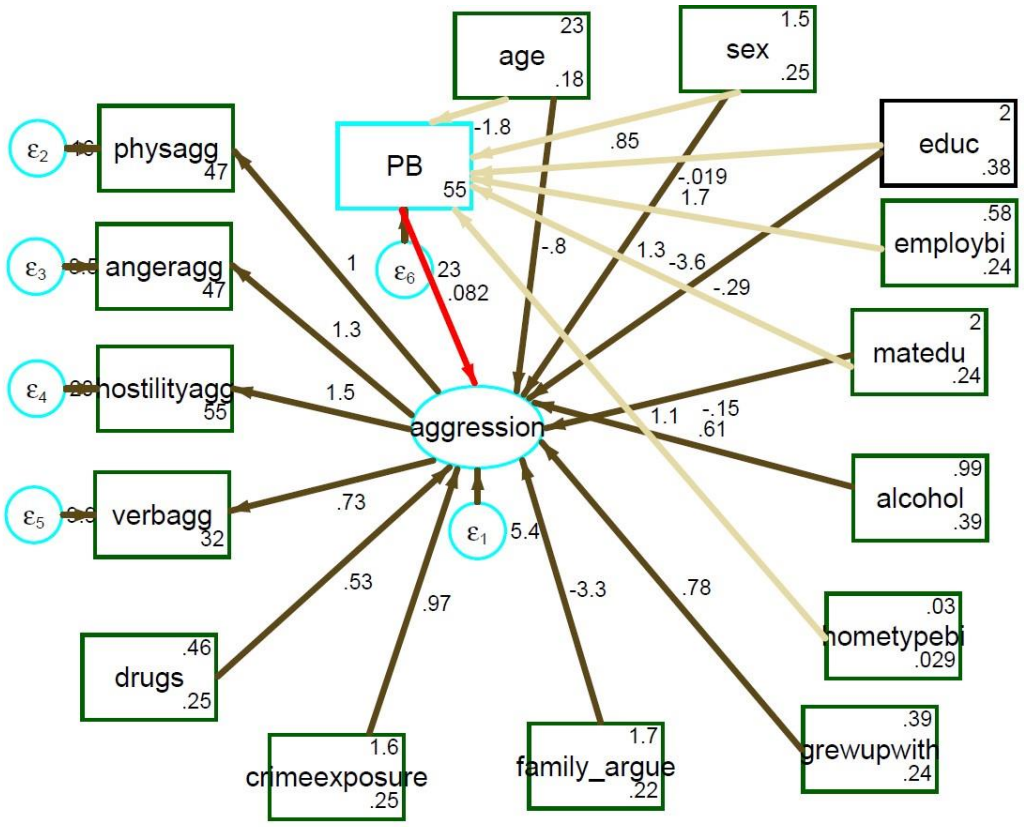


Figure 3: Path analysis between bone lead, aggression, and study predictors. (*fit statistics: X^2 (model vs saturated) =48.403 (0.337); RMSE=0.028 (pclose 0.736); CFI=0.970; TLI=0.957; SRMR=0.048 and coefficient of determination=0.43) (matedu=maternal education; hometypei=type of housing; family argue= exposure to family violence; crimeexposure=crime and violence in neighbourhood; employbi=occupational status)*

CHAPTER 5
5. DISCUSSION

This study intended to investigate the association between bone lead levels and aggression amongst the youth in Johannesburg. In the analysis section, we first described the demographic characteristics of the study participants and psychosocial factors that may contribute to aggressive behaviour as well as known determinants of lead exposure. In objective two, multivariable linear regression analysis was used

to assess the relationship between bone lead and aggression adjusting for known study confounders. Finally, for objective three, SEM was used to show direct and indirect pathways of explanatory variables and the response variable. In this chapter, we discuss the findings of the research in relation to what is known in the literature. In addition, new findings that have emanated from this secondary analysis will be discussed. The chapter will end with a conclusion from the findings, briefly mentioning some of the strength and limitations of this secondary study.

In objective one, description of the psychosocial, demographic and socioeconomic characteristics stratified by sex showed that the majority of the participants in the study did not grow up with both their parents and that most reported living in formal housing. Amongst others, these two factors are important predictors of aggressive behaviour and lead exposure. As mentioned in the literature, children who grow up in households with single parents were found to display aggressive behaviour compared to those who grew up with both parents (8, 47). The use of substances such as drugs and alcohol was more prevalent in males than in females. Alcohol and drug use among the youth have been associated with injuries, violent behaviour and incarceration (12, 63). Varying trends in sex difference in alcohol and certain illicit drug use such as heroin and hallucinogens have been seen, where in early and mid-adolescent years, substance use in females matches that of males, however, in late adolescence the prevalence of substance use tends to become higher in males than in females (12, 64).

Tibia bone lead levels were analysed in the study as a continuous variable to retain all values, including values below the detection limit and values lower than zero (65, 66). The summary measures of the distribution of bone lead levels in the study participants showed that both males and females had mean bone lead concentrations slightly lower than levels reported in other studies (6, 10). In this study, the mean bone lead levels were 8.09±4.42ppm in males and 9.44±6.07ppm in females, whereas Needleman reported mean bone lead levels of 11±32.7ppm in youth aged 12-18 years displaying delinquent behaviour (6) and Kosnett et al (1994) reported mean bone lead concentrations of 12.7±14.6ppm (range -12 to 69ppm) in

suburban community members aged 11 to 78 years (67). Bone lead levels greater than 25ppm have been reported to be associated with increased risk of delinquency (6).

While the participants in this study are the youth, one of the reasons for low levels of lead detected in tibial bone might be that the participants might not have been exposed to concentrations high enough to be retained in the bones for prolonged period of time. The other reason for such low levels compared to other studies is that other studies on bone lead reporting high levels are on middle aged and elderly participants (67, 68). While previous studies among children aged 14 to 15 years in the BT20 plus cohort found BLLs ranging from 1-28µg/dL, with a mean blood lead levels of 6.4±2.5µg/dL for males and 4.9±1.9µg/dL for females (17), literature has shown that children undergo a continuous remodelling of the bones where lead that has been incorporated into bones from environmental exposure is likely to appear later in adulthood where full skeletal size has been reached and remodelling slows down (67). Again, the BLLs in children from the BT20 cohort may not be high enough to be retained in the bones (8, 16, 17).

Sex and age have been shown to be important determinants of bone lead levels (67). The results in this study showed that the mean bone lead levels were slightly higher in females compared to males, even though the difference was not statistically significant. Kosnett et al (1994) did not observe a significant gender difference in bone lead after assessing the impact of age and sex on the bone lead concentrations in participants with background of environmental lead exposure in residential communities (67). In contrast, other studies have found that males would generally have higher blood and bone lead concentrations than females (8, 16, 69).

A summary of the mean aggression score showed that both males and females reported a higher score for physical aggression, followed by hostility and anger. The mean aggressive score in males was slightly higher for physical aggression compared to females even though the statistical test did not show a difference between males and females. These results are in agreement with other studies,

where males have been shown to report more direct forms of aggression such as physical aggression than females, irrespective of age (16, 70), whereas females report indirect forms of aggression such as hostility and anger (13). Nonetheless, a small sex difference has previously been detected for hostility (15, 63). To summarise the results in objective one, we found out that the mean of the total aggression score was higher in females than in males, though not significantly different. This indicated that females in this study may have a high-level of aggression compared to males. However, this observation might also be due to the high scores for anger, hostility and verbal aggression reported for females.

For objective two, a linear regression model was fitted to determine the association between continuous bone lead levels and aggression scores. In the multivariable model between bone lead and physical aggression, adjusting for known study confounders, bone lead was not associated with physical aggression. However, a unit increase in bone lead levels increased the score for physical aggression. Risk factors significantly associated and marginally associated with physical aggression score were exposure to family violence ($p<0.05$) and neighbourhood factors such as crime and violence in neighbourhood ($p<0.08$). Considering that the youth from this study resided in disadvantaged communities within the township, most are more likely to experience criminal and violence activities in their homes and in their neighbourhoods. This was reported elsewhere. As an example, Attar et al (1994) reported that children in adolescent years residing in disadvantaged neighbourhoods tend to experience stressful life events such as aggression than those in better neighbourhoods (71). Likewise, recent studies have shown that exposure to community violence can have an adverse impact on the emotional wellbeing and behaviour of youth (72). Similarly, children coming from families with violence will display behaviour problems in their lives (18, 73).

As indicated sex and age were kept in all final models. For age, a negative coefficient was obtained in a final model with physical aggression, indicating that as age increased the aggression score for physical aggression will decrease. Several studies have found that physical aggression tended to decrease steadily with age

(74). This may be attributed to maturity where, as age increases and children move into adulthood, they will be able to communicate and express their feelings rather than resort to physical aggression to resolve conflict. In addition, a negative coefficient for sex was obtained, where the score for physical aggression decreased in females. Females have previously been reported to display less forms of direct aggression such as physical aggression when compared to males (17). Females have been shown to display indirect forms of aggression. The reason for this may be that females tend to be able to express themselves more verbally than males (75).

A positive coefficient for sex was obtained when males were kept as the reference point in the models for anger, verbal aggression and hostility. These results indicated that the aggression score for these items increased in females. Indirect aggression has been reported as the aggressive style common in females, regardless of ethnicity and age groups studied, with verbal aggression being the second most reported and physical aggression being the least reported (76-78).

The model fitted for the association between bone lead levels and anger aggression showed a significant association. In addition, the model showed a positive coefficient indicating that an increase in bone lead increases the aggression score for anger. Reports on the psychological impact of anger shows that anger affects the brain by compromising the neurons in the hypothalamus where the stress response occurs (79). In the literature the adverse effect of lead on brain functioning has been demonstrated, thus accumulation of lead in the body may activate or trigger feelings of anger in individuals. Furthermore, it has been shown that individuals that exhibit anger usually have other aggressive behaviours such as hostility (79). Even though bone lead levels were not associated with physical aggression, hostility and verbal aggression, anger may be the prominent way of expressing aggression and hence the strong association in lead exposed individuals.

The final model between bone lead levels and anger showed that the history of family violence and neighbourhood factors were also associated with anger aggression. It is expected that children who grow up in a home environment where

there is shouting and violence will tend to be angry at their situation. It has also been found that feeling of depression and fear are displayed in individuals who display anger (79). The final model showing a significant association between bone lead levels and anger aggression was able to explain 29% of the variance between these variables. However, other factors not assessed in this study such as paternal relationship history, other childhood experiences of violence (bullying) could have improved the variance in the model explaining the relationship between bone lead levels and anger aggression.

Bone lead levels were not associated with verbal aggression and hostility, however the model showed a positive coefficient between age and verbal aggression, which indicated that as the participants' age increased the score for verbal aggression will tend to increase. This might be expected since when children enter into their late adolescent phase, most will tend to talk back to the parents and guardians and are able to express their emotions and opinions openly. Age was significantly associated with the aggression score for hostility, however a negative coefficient was obtained indicating that as age increases the aggression score for hostility decreased. The relationship between age and aggression has been reported (13), where some forms of aggression tend to decrease with age, which is what the results of the multivariable model showed for physical aggression and hostility. Inversely, verbal aggression and anger tend to increase with age.

The analysis of the final multivariable model showing the association between bone lead and total aggression score, adjusting for study confounders showed that there was no association. Nonetheless from the multivariable linear regression, we are able to ascertain the direction of the relationship between bone lead and aggression as well as other explanatory variables known to confound this relationship. An increase in bone lead increased the score for aggression. Exposure to family violence was found to be highly associated with total aggression score. In conclusion for this objective, bone lead is associated with aggression score for anger and not associated with other forms of aggressions, that is physical aggression, hostility and verbal aggression.

Being exposed to family violence increases the score for total aggression. In addition, the aggression score for physical aggression and anger decreases as age increases but the score for hostility and verbal aggression will increase as age increases. Overall, as age increases the total aggression score will decrease. There are several reasons that might be attributed to a conclusion of no significant association between bone lead levels and total aggression score, including as previously mentioned that the levels of lead measured in the bones in this study was not high enough to exhibit an effect as those reported in other studies. In addition, the small sample size of participants whose bone lead was measured in the cohort may reduce the power of the study.

For objective three, SEM was used for path analysis showing a direct effect of bone lead on aggression and indirect pathways where other determinants of bone lead were considered on the pathway to aggression. These risk factors may contribute to the overall lead concentration in the body indirectly increasing the adverse health outcome associated with lead. In the literature, educational attainment, employment status has been considered as proxies for socioeconomic variables that can affect bone lead levels (65, 80).

Lower education levels including that for maternal education status are indirect measures of poor socioeconomic status. As an example, in a normative aging study by Hu et al (1996) of middle aged to elderly males residing in an old community area of Boston, most participants reported a lower education level which was subsequently found to be strongly associated with higher lead levels (68). In this study, a negative path coefficient in SEM showed that maternal education was a significant predictor of bone lead levels, where a higher maternal education level showed a decrease in bone lead levels. Nonetheless, in a direct pathway between maternal education and aggression, we found no association, where higher education levels of the mothers indicated a decrease in aggressive behavior. In other studies, lower parental education has been associated with aggressive behaviour in children (81).

Disadvantaged communities in poor resourced countries have been shown to be at a higher risk for environmental lead exposures, including South Africa (20, 31). The sources of lead exposure for these communities is environmental pollution from houses previously painted with lead. In this study, the pathway between type of housing and bone lead levels showed a non-significant association. Considering that the BT20 cohort is a community study conducted in the south western township of Johannesburg were the homes are envisaged to be more than 50 years old (82), it was expected that formal housing possibly painted with leaded paint would show a strong association with bone lead levels.

Bone lead levels were found to decrease with age in the SEM model. This observation does not agree with other studies that showed that bone lead levels correlate with age were a one-year increase in age increases the tibia lead concentration in the exposed individuals (61, 68). This as indicated above might be because the population in this study is not as old as those reported in other studies (57). Lin et al (2004) indicated that the relationship between age and bone lead levels depends on age groups where the levels of bone lead increases at a greater rate in older individuals and this was shown to reflect differences in environmental lead exposure over time (49).

Cigarette smoking and consumption of alcoholic beverages have been linked with increasing blood lead and bone lead levels in the body. (67, 83). Cigarettes smoking was not measured in this study, however smoking has been thought to contribute to lead exposure from tobacco in the cigarettes which has been found to contain lead deposition and lead arsenate pesticides (83). On the other hand, alcohol beverages such as wine, cider and beer has also been found to contain lead content that may contribute to the overall lead levels in the body (83).

Study strength and Limitations

One of the strengths of this prospective cross sectional study is that a non-invasive sensitive technique was used to measure bone lead levels in the cohort. Research

that have used KXRF for repeated measurements of bone lead levels have indicated that the instrument provides high precision of estimates compared with chemical analyses (84). Secondly, a reliable validated tool was employed to quantify aggression scores in the study. Nonetheless, this secondary study had several limitations, including that a limited sample size was used for the analysis and therefore the results may not be representative of the population in the cohort. Increasing the sample size may decrease the probability of type II error in the analysis, therefore increasing the probability of rejecting the null hypothesis of no association in the study. Other limitations include the potential for bias such as recall bias where participants may tend to over report or under report their aggressive behaviour patterns.

Finally, the small variance in the linear regression and coefficient of determination in the SEM indicate that not all risk factors that can explain the relationship between bone lead levels and aggression were included in the study. For example, information on variables such as occupational history related to lead exposure, smoking history, housing age or duration of residence at the current address, as well as physical appearance of the homes in terms of peeling paint were not collected. In addition, other risk factors for aggression was not included in the psychosocial questionnaire, such as paternal history. Food insecurity was also not assessed in the study. Research has linked poor nutrition, which is more common in poorer communities with low income brackets with increase in the absorption of lead in the body (85).

CONCLUSION

The study of aggressive behavior in young adults is important due to a number of possible negative public health outcomes, including youth violence (16, 50), and participation in criminal activities later in life (52, 86). In this study, the association between bone lead levels, a measure of lifetime lead exposure with aggressive behaviour was assessed. The results showed that bone lead levels were associated with the aggression score for anger. Nonetheless, when the four scales that are used to measure aggression were combined, there was no association between bone lead

levels and the total aggression score. Limitations in sample size may be one of the reason for no association. Risk factors for aggression in the multivariable analysis predicting aggression were history of family violence and neighbourhood crime. Finally, path analysis using SEM showed a significant direct effect between maternal education and bone lead were a higher level of maternal education was found to decrease bone lead levels. The study however provides a preliminary overview in the relationship between bone lead and aggression. Thus, longitudinal studies employing a larger sample size in South African youth may be necessary to investigate the relationship of these two important public health factors. The information may be crucial in the drafting of policies designed to combat crime in South Africa.

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APPENDICES

Appendix 1: Plagiarism declaration report





PLAGIARISM DECLARATION TO BE SIGNED BY ALL HIGHER DEGREE STUDENTS

I _____**Nonhlanhla Tlotleng**_____ (Student number: _**319233**_____) am a student registered for the degree of __**MSc Epidemiology (Epidemiology and Biostatistics)** _____ in the academic year __**2020**_____.

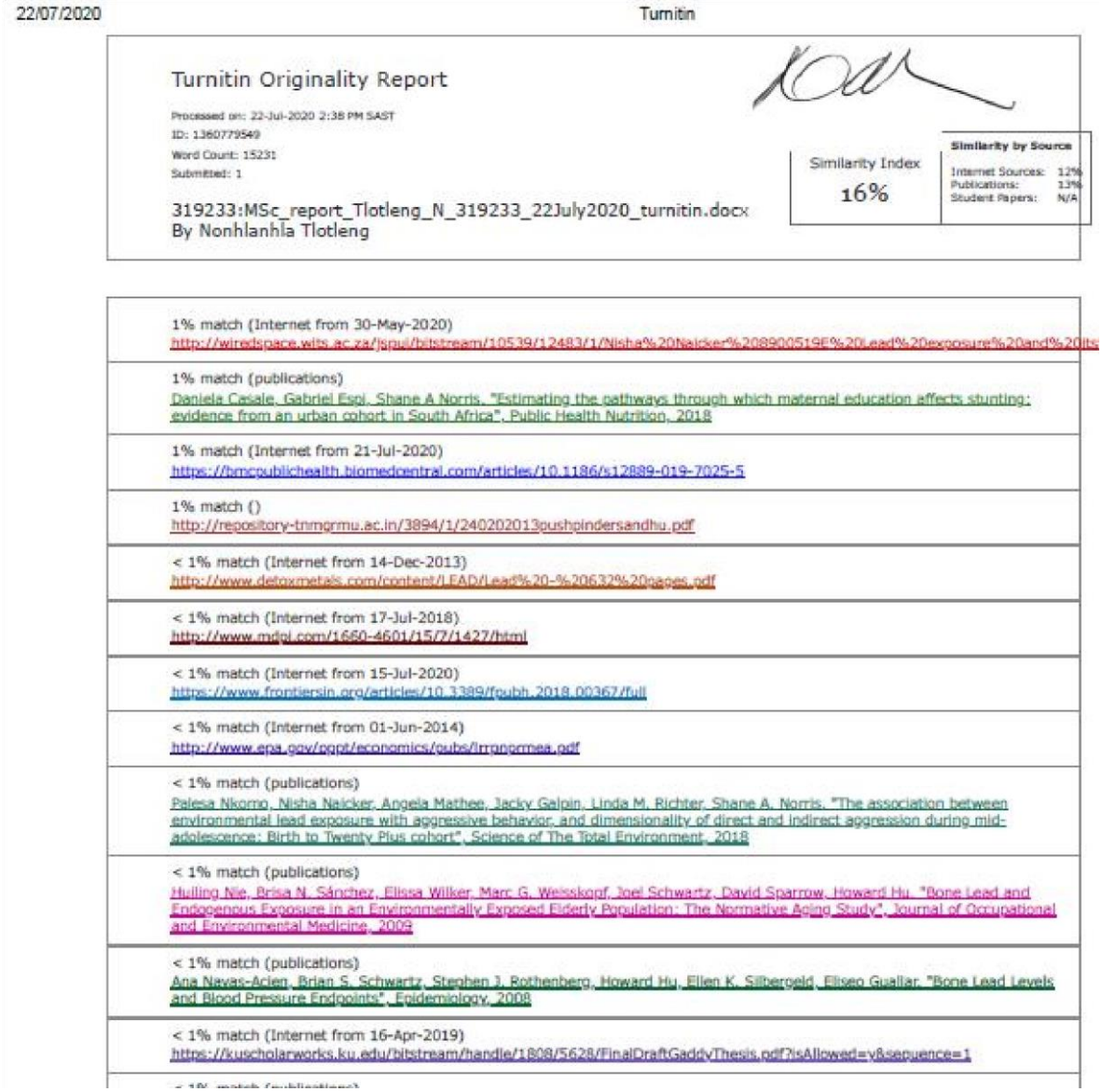
I hereby declare the following:

- I am aware that plagiarism (the use of someone else's work without their permission and/or without acknowledging the original source) is wrong.
- I confirm that the work submitted for assessment for the above degree is my own unaided work except where I have explicitly indicated otherwise.
- I have followed the required conventions in referencing the thoughts and ideas of others.
- I understand that the University of the Witwatersrand may take disciplinary action against me if there is a belief that this is not my own unaided work or that I have failed to acknowledge the source of the ideas or words in my writing.
- I have included as an appendix a report from "Turnitin" (or other approved plagiarism detection) software indicating the level of plagiarism in my research document.



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Appendix 2: Turnitin Cover page



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Huiling Nie, Brisa N. Sánchez, Elissa Wilker, Marc G. Weisskopf, Joel Schwartz, David Sparrow, Howard Hu, "Bone Lead and Endogenous Exposure in an Environmentally Exposed Elderly Population: The Normative Aging Study", Journal of Occupational and Environmental Medicine, 2009

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Appendix 3: Ethics clearance certificate

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

R14/49 Dr Nonhlanhla Tlotleng

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M191116

NAME: (Principal Investigator)	Dr Nonhlanhla Tlotleng
DEPARTMENT:	School of Public Health National Institute for Occupational Health National Health Laboratory Services
PROJECT TITLE:	Association between bone lead levels and aggression in the Birth to Twenty Plus Cohort
DATE CONSIDERED:	29/11/2019
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Dr Nisha Naicker
APPROVED BY:	Dr CB Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	29/11/2019

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary on the Third Floor, Faculty of Health Sciences, Phillip Tobias Building, 29 Princess of Wales Terrace, Parktown, 2193, University of the Witwatersrand. I/we fully understand the conditions under which I am/we are authorized
to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report**. The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. In this case, the study was initially reviewed in **November** and will therefore be due in the month of **November** each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix 3: Buss-Perry Aggression questionnaire

Various studies have shown the there are environmental factors that may contribute or deter individuals from aggressive behavior. In this questionnaire you are going to be asked questions about your aggression patterns; school/ education and occupational status home environment; attitude towards your neighborhood; profile of substance abuse; general perceptions of crime and personal safety; experience at home; exposure to crime and violence; and demographics

SECTION A: BUSS-PERRY AGGRESSION QUESTIONNAIRE: A five point scale will used to indicate how uncharacteristic or characteristic each of the following statements is in describing you.					
	Extremely uncharact-eristic of me	**Somewhat uncharact-eristic of me**	**Neither uncharacteristic nor characteristic of me**	**Somewhat characteristic of me**	**Extremely characteristic of me**
1. Some of my friends think I am a hothead.					
2. If I have to resort to violence to protect my rights, I will.					
3. When people are especially nice to me, I wonder what they want.					
4. I tell my friends openly when I disagree with them.					
5. I have become so mad that I have broken things.					
6. I can't help getting into arguments when people disagree with me.					
7. I wonder why sometimes I feel so bitter about things.					
8. Once in a while, I can't control the urge to strike another person.					
9. I am an even tempered person.					
10. I am suspicious of overly friendly strangers.					
11. I have threatened people I know.					
12. I flare up quickly but get over it quickly.					

13. Given enough provocation, I may hit another person.					

14. When people annoy me, I may tell them what I think of them.					
15. I am sometimes eaten up by jealousy.					
16. I can think of no good reason for ever hitting a person.					
17. At times I feel I have gotten a raw deal out of life.					
18. I have trouble controlling my temper.					
19. When frustrated, I let my irritation show.					
20. I sometimes feel that people are laughing at me behind my back.					
21. I often find myself disagreeing with people.					
22. If somebody hits me, I hit back.					
23. I sometimes feel like a powder keg ready to explode.					
24. Other people always seem to get breaks.					
25. There are people who pushed me so far that we came to blows.					
26. I know that “friends” talk about me behind my back.					
27. My friends say that I’m somewhat argumentative.					
28. Sometimes I fly off handle for no good reason.					
29. I get into fights a little more than the average person.					

SECTION B : SCHOOLING/ EDUCATION AND OCCUPATIONAL STATUS

1.	**Have you ever attended school?**	1= yes 2= no ***(If no, skip to # 6)***	

2.	**If YES, What is the highest level of education you have completed?**	1= grade 5 or less ***(skip to #4)*** 2= grade 6 to 8 ***(skip to #4)*** 3= grade 9 to 10 ***(skip to # 4)*** 4= grade 11 ***(skip to # 4)*** 5= grade 12 7= tertiary level X= other (specify)	

3.	**What is the highest post-school qualification you have completed?**	1= bachelor/undergraduate degree 2= post graduate degree 3= post graduate diploma 4= trade certificate 5= other certificate 6= other (specify)	
4.	**In addition to your schooling, have you received any form of skills training?**	1= yes 2= no **(If no, skip to #6)**	
5.	**If YES, what was the nature of training?**	1= computer literacy 2= computer programming 3= book keeping 4= trade skills, such as carpentry, panel work, etc. 5= other (specify)	
6.	**IF NEVER ATTENDED SCHOOL OR NOT COMPLETED MATRIC/GRADE 12…. THEN** **Ask: why did not complete your schooling training?** **(Multiple response – Max 3)**	1= completed matric 2= failed 3= could not afford it 4= did not enjoy it 5= did not see the point 6= family pressure 7= had to work for money 8= moved out of area 9= had a child 10= expelled/ asked to leave X= other (specify)	
7.	**If ATTENDED SCHOOL, who paid for this?**	1= both parents 2= mother only 3= father only 4= partner 5= older brother or sister 6= grandparent (s) 7= step parent (s) 8= other relatives 9= non relatives 10= no one X= other (specify)	

8.	**Have you ever been employed, either part-time or full-time?**	1= no- I have never been employed 2= casual labour/ temporal labour (short-term labour) 3= part-time employment 4= self-employed 5= full-time employed 6= other (specify)	
9.	**Can you tell me if you are/were employed?**	1= no, (was) seeking work 2= no, (was) not seeking work 3= yes, casual labour/ temporary labour (short-term labour) 4= yes, part-time employed 5= yes, self employed 6= yes, full-time employed X= other (specify)	

10.	**When you need/ needed money for clothes, shoes and such where do/did you get the money from?**	1= employment 2= both parents 3= mother only 4= father only 5= partner 6= old brother or sister 7= grandparent (s) 8= step parent (s) 9= relatives 10= non-relatives 11= friends 12= handouts (begging) 13= donations 14= allowances 15= criminal activity X= other (specify)	

SECTION C: HOME ENVIRONMENT

The following questions pertain to your home and family. *Past tense will be used where appropriate when asking the questions to the convicted offenders as they are now held in a juvenile correctional service.*

1.	**How long have you live/ lived in your household?**		Months/Years
2.	**How many people live/ lived in the household?**		No.
3.	**How many people between the ages of 12 and 25 live/ lived in the household?**		No.
4.	**How many people living in the household have/ had permanent work or a stable source of income (excluding grants)?**		No.

5.	**Does/did anyone in the household own a motor vehicle?**	1= yes 2= no	
6.	**Does/did anyone in the household own a licensed firearm?**	1= yes 2= no	
7.	**Does/did anyone in the household own an unlicensed firearm?**	1= yes 2= no	
8.	**Does/did anyone in the household own any other kind of weapon (such as knife, or panga etc.)?**	1= yes 2= no	
9.	**Does/ did anyone in the household receive any form of government grant (e.g. disability, child care, foster care, government pension, etc.)?**	1= yes 2= no	
10.	**Would you say that you always have/ had enough food to eat in your household?**	1= yes 2= no	

11.	**How many nights out of a week do/ did you go to bed hungry?**		No.
Please tell me if you agree or disagree with the following statements			
12.	**We argue a lot in our family**	1= agree 2= disagree	
13.	**People in my family hardly ever lose their temper**	1= agree 2= disagree	
14.	**People in my family sometimes hit each other when they are angry**	1= agree 2= disagree	
SECTION D: ATTITUDE TOWARDS NEIGHBOURHOOD			
The following questions pertain to your neighbourhood (i.e. area in which you live/ lived) and how you feel about living there. Please tell me if you agree or disagree with the following statements in respect of the neighbourhood in which you live/ lived….			
1.	**I like my neighbourhood**	1= agree 2= disagree	
2.	**I would like to move out of my neighbourhood**	1= agree 2= disagree	
3.	**If I had to move I would miss my neighbourhood**	1= agree 2= disagree	
4.	**There are places/ areas in my neighbourhood that I avoid because I am scared of them**	1= agree 2= disagree	
5.	**I know my neighbour (s) by name**	1= agree 2= disagree	
6.	**Most people in my neighbourhood can be trusted**	1= agree 2= disagree	

7.	**In my neighbourhood, one has to be alert or someone is likely to take advantage of you**	1= agree 2= disagree	
8.	**Most people in my neighbourhood are willing to help you if you need it**	1= agree 2= disagree	
9.	**People move in and out of this neighbourhood a lot**	1= agree 2= disagree	
10.	**There are a lot of people in my neighbourhood whom I could talk to about something that is important to me**	1= agree 2= disagree	
11.	**I have many friends in my neighbourhood**	1= agree 2= disagree	
12.	**Most young people in my neighbourhood trust each other**	1= agree 2= disagree	
13.	**Most young people in my neighbourhood can be trusted**	1= agree 2= disagree	

Please tell me if any of the following describe your neighbourhood (area in which you live/ lived)

14.	**Lots of crime?**	1= yes 2= no	
15.	**Lots of fights?**	1= yes 2= no	
16.	**Lots of empty or abandoned buildings?**	1= yes 2= no	
17.	**Lots of graffiti?**	1= yes 2= no	
18.	**Generally, how safe do you feel in your neighbourhood?**	1= very safe (skip to # 20) 2= somewhat safe (skip to # 20) 3= somewhat unsafe 4= very unsafe	
19.	**IF ANSWERED VERY UNSAFE OR SOMEWHAT UNSAFE IN #18 then ask: why would you say that?**	1= I have been a victim of crime in the past and scared of repeat 2= crime is common in this area 3= there are often/ always unsavoury people in this area 4= I feel alone/ isolated 5= there is so much crime reported in the news that I am scared of it happening to me X= other (specify)	
20.	**How do you think crime in your neighbourhood has changed in the last three years?**	1= increased 2= decreased 3= stayed the same	

21.	**If you wanted to get some beer, wine, hard liquor (like vodka, brandy or other spirits), how easy would it be for you to get some?**	1= very hard 2= hard 3= easy 4= very easy	
22.	**Do you know where you can buy drugs in your neighbourhood?**	1= yes 2- no	
23.	**If you wanted to get some marijuana or dagga in your neighbourhood, how easy would it be for you to get some?**	1= very hard 2= hard 3= easy 4= very easy	
24.	**Do you personally know anyone in your household or any of your family and friends who have bought drugs in the past 12 months?**	1= yes 2= no	
25.	**I do not want to know names, but does anyone in your household or do any of your family and friends use or sell drugs?**	1= yes 2= no	
I do not want you to tell me names, but do you personally, know any people in your neighbourhood who…….			
26.	**Smoke marijuana/dagga/dope?**	1= yes 2= no	

27.	**Selll or deal in drugs (other than dagga)?**	1= yes 2= no	
28.	**Buy any drugs (other than dagga)?**	1= yes 2= no	
29.	**Do any other things that may get them into trouble with the police, such as stealing, mugging, selling stolen goods or assaulting others?**	1= yes 2= no	

SECTION E: PROFILE OF SUBSTANCE ABUSE

READ OUT: The next several questions concern alcohol and/or drugs (both those considered legal and illegal) that you may have consumed. The questions about drugs that you may have bought over the counter or obtained from a doctor refer only to drugs that you have taken to achieve effects other than what they are medically prescribed for. Please answer the questions and remember that everything that you tell me is confidential.

Question	**Code**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**

	Questions 1, 8 & 10 1= yes 2= no **Questions 3-7** 1= never 2=once/twice 3= monthly 4= weekly 5= daily	**Alcohol**	**Cannabis- Marijuana- dagga**	**Cocaine- crack, powder, rock**	**Amphetamines- uppers, speed, diet pills**	**Inhalants, including glue**	**OTC substances- sleeping pills, sedatives**	**Hallucinogen- LSD, acid, pcp including 'e' or ecstacy**	**Opiates- Heroin, morphine, codeine**	**Mandrax- white pipe**	**Tik**	**Any other illegal substances specify (**
1. In your life have you ever used any of these drugs?												
2. When you first tried it/them how old were you?	In years											
3. In the past 12 months how often have you used?												
4. In the past 12 months how often have you had a strong desire or urge to use?												

5. In the past 12 months how often has your use of …. led to health, social, legal or financial problem?												
6. In the past 12 months how often have you failed to do what was expected of you because of your use of …?												
7. In the past 12 months how often has your use of …made you do something that may have been wrong or against the law?												
8. In the past 30 days have you used your drug/s of choice?	If NO, skip to # 12											

9. Out of the past 30 days, how many days did you use…?	In days											
10. In the past 7 days have you used…												
11. In the past 7 days, how much money did you spend on..?	Rands											
12. Have you ever used the firearm whilst under the influence of…?	1= yes 2= no											
13. Has a friend or relative, or anyone else, ever expressed concern about your use of…?												
14. Have you ever tried and failed to control, cut down, or stop using..?												
15. Have you ever sold any…?												
16. Have you ever used any…..by injection?												
If alcohol ever used, answer the following questions. If not skip to next section.												

17.	**How much do drink on average on weekdays (per day)?**	1= no drinking during the week 2= less than 1 drink per day 3= 1-2 drinks per day 4= 3-4 drinks per day 5= 5 or more drinks per day 6= communal drinking	
18.	**How much alcohol do you drink on average on weekends?**	1= no drinking over the weekend 2= less than 1 drink per day 3= 1-2 drinks per day 4= 3-4 drinks per day 5= 5 or more drinks per day 6= communal drinking	
SECTION F: GENERAL PERCEPTIONS ON CRIME AND PERSONAL SAFETY			
I would like to ask you some questions on how safe you feel in different places…			
1.	**Generally, what are the things that make you the most scared?** **(MULTIPLE RESPONSE – MAX 3)**	1= murder 2= rape/ sexual assault 3= fighting 4= bullying 5= theft/ mugging 6= vigilantes 7= verbal abuse/ being teased 8= guns 9= getting aids 10= gangs 11= taking public transport 12= walking to/ from school 13= nothing X= other (specify)	
2.	**You do not have to name them, but do you personally know anyone who makes a living from committing crime in your neighborhood?**	1= yes 2= no (If no skip to the next section)	
3.	**If YES, what kind of crime does this person do** **(ONLY ONE ANSWER)**	1= theft 2= robbery 3= assault (including beating people up) 4= housebreaking 5= vehicular crimes (including high jacking) 6= drug-related crimes X= other (specify)	
SECTION G: EXPERIENCES AT HOME			

1.	**Do you feel safe when you are at home (that is place where you live)?**	1= yes 2= no	
2.	**If NO, why do you not feel safe at home?** **(MULTIPLE RESPONSE – MAX 3 ANSWERS)**	1= scared of being hurt 2= scared of criminals 3= scared of parents/ caregiver 4= scared of brother(s)/ sister(s) 5= scared of other relatives/ friends 6= scared of being disciplined	
		X= other (specify)	
3.	**Do you ever fear traveling to and from home?**	1= yes 2= no	
4.	**Is there any particular place at your home that you are scared of?**	1= yes 2= no (If no skip to #6)	
5.	**If YES, then where within your home?**	1= inside the home 2= outside the home (garden etc.) X= other (specify)	
6.	**Has anybody threatened to hurt you, scare you or harm you in any way, or actually hurt you when you have been at home?**	1= yes 2= no (If no skip to #10)	
7.	**If YES, who was the person?** **(IF MORE THAN ONCE, THEN REFER TO LAST INCIDENT)**	1= both parents 2= mother only 3= father only 4= partner 5= older brother or sister 6= grandparent(s) 7= step parent(s) 8= other relatives 9= non relatives 10. no one X= other (specify)	
8.	**If yes to #6, how often has this person hurt/scared/harmed you?**	1= once 2= two to five times 3= six to ten times 4= more than ten times	

9.	**If YES to #6, thinking of the last incident (if more than one) what did this person do?**	1= hurt me (punched/ kicked) 2= threatened to hurt me 3= took something from me 4= threatened to hurt someone else I know 5= scared me into doing something that I did not what to do X= other (specify)	
10.	**Have you ever been forced to do something that you felt was wrong, and you did not want to do, by someone at home?**	1= yes 2= no	
11.	**When you have done something wrong at home, does anyone spank, hit or otherwise hurt you for what you have done?**	1= yes 2= no	
12.	**Has anyone at home ever threatened say something to others that will stigmatize you**	1= yes 2= no	
	(make you look bad in front of others)		

SECTION H: PART 1- EXPOSURE TO CRIME AND VIOLENCE

I would like to ask you about crime you may have experienced. Can you tell me if you personally experienced any of the following…

		Ever in your life? **1= yes** **2= no**	**If YES, did this crime occur in the past 3 years (since 2008)** **1= yes** **2= no**	**Thinking of the last incident, did this crime occur in your area?** **1= yes** **2= no**
1.	**Any crime**			
2.	**Assault**			
3.	**Robbery**			
4.	**Home burglary**			
5.	**Theft of vehicle or bicycle**			
6.	**Theft of personal property, crops, livestock etc.**			
7.	**High jacking of a vehicle or bicycle**			
8.	**Sexual assault/ Rape**			

9.	**Deliberate damage to property**			

10.	**IF YES TO ANY OF THE ABOVE, THEN ASK, After the crime, did you feel that you wanted to get the perpetrator back for his or her actions? (i.e. get revenge on the perpetrator)?**	1= yes 2= no (If no skip to # 13)	
11.	**If YES to # 10. Did you aver act on these feelings?**	1= yes 2= no	
12.	**If YES to # 11, what did you do?**		

PART 2- EXPOSURE TO CRIME AND VIOLENCE

Has anyone else in your household (i.e. besides you) experienced any of the following…

	1= yes 2= no	**Ever?**	**If YES, did this crime occur in the past 3 years (since 2008)**	**Thinking of the last incident, did this crime occur to your area?**
13.	**Any crime**			
14.	**Assault**			
15.	**Robbery**			
16.	**Home burglary**			
17.	**Theft of vehicle or bicycle**			
18.	**Theft of personal property/ crops/ livestock**			
19.	**High-jacking of a vehicle or bicycle**			
20.	**Sexual assault/ Rape**			
21.	**Deliberate damage to property**			
22.	**Murder**			

PART 3- EXPOSURE TO CRIME AND VIOLENCE

24.	**Which types of crime are you most scared of in your area?** **(MULTIPLE RESPONSE – MAX 3 ANSWERS)**	1= assault 2= robbery 3= home burglary 4= theft of vehicle 5= theft of personal property 6= high-jacking of vehicles 7= theft of crops/ livestock 8= sexual assault/ rape 9= deliberate damage to property	

		10= theft of bicycles 11= murder X= other (specify)	
25.	**Generally, who do you think is most likely to commit crime in your area?** **(MULTIPLE RESPONSE – MAX 3 ANSWERS)**	1= people from outside the area 2= people living in the area 3= unemployed people 4= youths/ teenagers X= other (specify)	
26.	**Why do you think these people commit these crimes?** **(MULTIPLE RESPONSE – MAX 3 ANSWERS)**	1= poverty 2= jealousy 3= unemployment 4= drugs 5= lack of means of survival 6= peer pressure 7= habit 8= organized crime/ gang-rituals or initiation 9= easy way out/ laziness 10. need to impress X= other (specify)	
Now I am going to ask you some questions about people you might have seen being hurt.			
27.	**Have you ever seen anyone in your family or household hurt another member of your family or household on purpose? By hurt I mean, punched, kicked, physically pushed, hit or slapped, or attacked with any weapon such as a knife, stick, panga or gun?**	1= yes 2= no	
28.	**If YES, how old were you when you saw this (the first time)?**		Years
29.	**Was a weapon used in this act?**	1= yes 2= no	
30.	**If YES to # 28, what weapon was used?**	1= gun 2= knife 3= panga 4= stick X= other (specify)	
31.	**Did the household member who was hurt have any physical sign of injury (such as bruises, cuts, etc.)**	1= yes 2= no	
32.	**Did the household member who was hurt go to see a doctor, clinic or hospital for their injuries?**	1= yes 2= no	

33.	**What relation was the person who was hurt (that is the victim) to you?**	1= mother 2= father 3= grandparent 4= brother(s) or sister(s) 5= child 6= other relative 7= friend X= other (specify)	
34.	**What relation was the person who was hurting the other person (i.e. the attacker) to you?**	1= mother 2= father 3= grandparent 4= brother(s) or sister(s) 5= child 6= other relative 7= friend X= other (specify	
35.	**Was the attacker under the influence of drugs or alcohol at the time of the act?**	1= yes 2= no	
36.	**Have you ever seen anyone being hurt by someone else, outside of your household? By hurt I mean, punched, kicked, physically pushed, hit or slapped, or attacked with any weapon such as a knife, stick, panga or gun?**	1= yes 2= no	
37.	**How old were you when you saw this? (IF WITNESSED MORE THAN ONCE ASK ABOUT THE FIRST TIME THAT YOU CAN REMEMBER)**		Years
38.	**Can you tell me where this happened?**	1= home 2= at school 3= in this area, but not at home 4= outside of this area X= other (specify)	

39.	**Did you know the person(s) who was attacked?**	1= yes 2= no	
40.	**How often did you see this happen?**	1= once 2= two to five times 3= six t ten times 4= more than ten times	
41.	**Was the attacker under the influence of drugs or alcohol?**	1= yes 2- no	
42.	**Was the person that you saw being attacked related to you?**	1= yes 2= no	

43.	**If YES, who was the person that was attacked?**	1= mother 2= father 3= grandparent 4= brother(s) or sister(s) 5= child 6= other relative 7= friend X= other (specify)	
44.	**Do you know the person who was hurting or attacking the victim?**	1= yes 2= no	
45.	**If YES to # 44, who was the person?**	1= mother 2= father 3= grandparent 4= brother(s) or sister(s) 5= child 6= other relative 7= friend X= other (specify	
46.	**Other than the incident above, how many times have you witnessed someone outside your household being hurt?**	1= one 2= two to five times 3= six to ten times 4= more than ten times	
SECTION I: DEMOGRAPHICS			
2.	**Where did you grow up? (city/town/village and area)**		
3.	**Did you grow up with both parents at home?**	1= yes 2= no	
4.	**If No, who do/did you live with the most when you were growing up?**	1= mother only 2= father only 3= older brother or sister 4= grandparent(s) 5= step parent(s) 6= other relatives 7= non relatives X= other (specify)	

5.	**What is your home language?**	1= Afrikaans 2= English 3= IsiNdebele 4= Sepedi 5= Sesotho 6= Setswana 7= SiSwati 8= Xitsonga 9= Tshivenda 10= IsiXhosa 11= IsiZulu X= other
6.	**What is your mother's or maternal guardian's level of education?**	1= no formal education 2= ≤ Std. 3/≤ grade 5 3= Std. 4-5/ grade 6-7 4= Std. 6-8/ grade 8-10 5= Std. 9-10/ grade 11-12 6= post school training
7.	**Do you have a girlfriend /boyfriend?**	1= yes 2= no
8.	**If YES to #7, how may girlfriends/ boyfriends do you have?**	
9.	**Has anyone in your household ever been in prison?**	1= yes 2= no
10.	**If YES to #9, who in your family has been in prison?**	1= both parents 2= mother only 3= father only 4= older brother or sister 5= grandparent(s) 6= step parent(s) 7= other relatives 8= non relatives X= other (specify)
11.	**If YES to #9….is this family member(s) currently in prison serving a prison sentence?**	1= yes 2= no
12.	**Is having a family member in prison a huge embarrassment in your family?**	1= yes 2=no
13.	**Socio-Economic Status (SES) Data**	
13.1	**Type of home**	1= free standing house/townhouse/duplex 2= flat, multiple 3= flat, single 4= RDP/ low income 5= hostel 6= squat/shack/other informal room housing X= other (specify)

13.2	**Is your home…….**	1= Owned 2= Rented another person 3= Rental local authority 4= Provided employer
		X= Other (specify)
13.3	**Water usage**	1= Sole Usage 2= Shared 3= No Access
13.4	**Water facilities**	1= Indoor running hot and cold 2= Indoor running cold water 3= Tap outside the house 4= Water from other source
13.5	**Toilet usage**	1= Sole Usage 2= Shared 3= No Access
13,6	**Toilet facilities**	1= Flush toilet inside the house 2= Flush toilet outside the house 3= Bucket System 4= Other (specify)
13.7	**Disposal of refuse**	1= Own garbage bin 2= Own refuse heap 3= Communal heap 4= Leave in street 5= Other (specify)
13.8	**Do you make use / have electricity in your home?**	1= yes 2= no
13.9	**Do you have a TV in your home?**	1= yes 2= no
13.10	**Do you have a Car**	1= yes 2= no
13.11	**Do you have a Fridge in your home?**	1= yes 2= no
13.12	**Do you have a Washing Machine in your home?**	1= yes 2= no
13.13	**Do you have a Telephone in your home?**	1= yes 2= no
COMMENT: Please make any comments you wish about the questionnaire or the study.		

WITH YOUR PERMISSION, MAY WE RETURN TO ASK YOU MORE QUESTIONS?

IF YES, please give us your Contact number

END OF QUESTIONNAIRE