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Environmental lead exposure and socio-behavioural adjustment in the early teens: The birth to twenty cohort

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ABSTRACT

Lead exposure remains high in South Africa. Environmental lead exposure has been associated with behaviour problems in childhood and adolescence. The objective of this study was to determine the relationship between blood lead levels and socio-behavioural problems among young adolescents in the Birth to Twenty cohort (Bt20).

The uniquely South African Bt20 cohort started in 1989 and is a long-term prospective follow-up study of the health and well-being of children born in the Greater Johannesburg area. The total analytical sample size consisted of 1041 adolescents (487 males and 554 females). Blood lead levels were obtained from whole venous blood that was collected. Thirty two items representing Rule-breaking and Aggressive behavioural characteristics from the Youth Self Report (YSR) were assessed. Bivariate and multiple regression analyses were conducted to assess for associations between blood lead levels and socio-behavioural problems at 13 years of age.

The geometric mean blood lead level was significantly (P value <0.001) higher in boys (6.0 μg/dl) compared to girls (4.5 μg/dl). In the total analytical sample four behavioural items were significantly associated with the geometric mean blood lead levels. When stratifying the sample by sex, the bivariate analyses showed that boys' blood lead levels were significantly associated with four types of aggressive behaviour. There were no significant associations found in girls. The multivariate analysis was conducted in the boys sample and after adjusting for socio-economic factors "Attacking People" remained significantly associated with blood lead levels.

High blood lead levels are associated with anti-social and destructive behaviour amongst boys in their early teens. However, the relationships are complex and confounded by other aspects of adversity.

1. Introduction

Blood lead levels in South Africa continue to be high compared to resource-rich countries where the mean blood lead levels in children are approximately 3.0 μg/dl (Koller et al., 2004). There are no routine screenings and monitoring processes for lead exposure in South Africa, thus evidence for environmental lead exposure has been determined from several cross-sectional epidemiological studies. In the Western Cape inner city school children aged 6 to 8 years had mean blood lead levels ranging from 14.0 to 16.0 μg/dl in 1991 (von Schirnding et al., 1991, 2001). Over 90% had blood lead levels greater than 10.0 μg/dl. In Johannesburg it was found that in 1995, 78% of children aged 6 to 8 years had blood lead levels >10.0 μg/dl with a mean blood lead level of 11.9 μg/dl (Mathee et al., 2002). By 2002, a follow up study in the same schools showed that the mean blood lead level dropped to 9.1 μg/dl, but 10% of children had blood lead levels >10.0 μg/dl (Mathee et al., 2004). This change was attributed to the introduction of unleaded petrol in 1996 (Mathee et al., 2006). Thus despite some reductions, the detrimental health effects due to lead exposure remains a major public health challenge in South Africa.

One of the potential negative health outcomes of lead exposure is neurotoxicity and its effect on behaviour. Studies have shown an association between lead exposure and behavioural problems in children. These problems include characteristics of Conduct Disorders and Oppositional Defiant Disorders that are described in the

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Diagnostic and Statistical Manual of Mental Disorders —Fourth Edition (DSM IV, 2000) and have been shown to be raised among children exposed to lead. This type of behaviour includes temper tantrums, argumentativeness, active defiance and refusal to comply with adult requests and rules, deliberate attempts to annoy and upset people, frequent anger and resentment, mood instability, substance abuse, aggression towards people and animals, destruction of property, and deceitfulness, lying or; stealing (DSM IV, 2000; AACAP).

In 1994 Bellinger et al. used the Teacher Report Form of the Child Behaviour Profile to assess childhood behavioural problems and its association with blood and dentine lead levels (Bellinger et al., 1994). This study found that tooth lead levels, used as an indicator of postnatal lead exposure in 8-year-olds, were associated with higher behavioural problem scores (Bellinger et al., 1994). Needleman in 1996 showed that in 11-year-old boys there was a significant association between higher bone lead levels and behavioural problems, specifically aggression, attention and delinquency as assessed on the Child Behaviour Checklist (Needleman et al., 1996). These retrospective cross-sectional studies have been cited to suggest a possible causal association between lead exposure and problem behaviour. The Cincinnati Lead Study, a longitudinal study, showed that in children aged between 15 and 17 years there was a significant association between lead exposure and antisocial behaviour as determined by the Self Report and Parental Report of Delinquent Behaviour (Dietrich et al., 2001). The longitudinal Port Pirie Cohort study found similar results using the Child Behaviour Checklist (Burns et al., 1999). These latter studies indicate that behavioural problems may be manifest at blood levels lower than 10.0 μg/dl.

Socio-behaviour problems in adolescents are often both an outcome of earlier developmental difficulties and a precursor for antisocial and/or criminal behaviour later in life (Liu and Wuerker, 2005). Studies have reported that violent criminals were more likely to have higher childhood or lifetime blood lead concentrations (Nevin, 2000, 2007; Stretesky and Lynch, 2001; Wright et al., 2008). Besides lead exposure, risk factors for socio-behaviour problems include socio-economic status of an individual and other adversities in the home and social environment (Webster-Stratton and Taylor, 2001; Needleman et al., 2002), all of which act as possible confounders in exploring the relationships between lead and socio-behavioral adjustment. For example, children from lower socio-economic strata frequently have an increased risk of exposure to lead, violence and social problems as well as decreased resources (financial or compensatory experiences) to cope with the effects of exposure (Bellinger, 2008; Tong et al., 2000). An earlier study on the Bt20 cohort showed that at 13 years of age that low socio-economic status and having a high cord blood lead level increased the risk of lead exposure (Naicker et al., 2010). There is evidence that behavioural problems due to lead exposure may be attenuated by higher socio-economic status and better social conditions (Bellinger, 2008). In South Africa where poverty is pervasive, lead exposure may contribute to socio-behavioural abnormalities.

There are no other known studies that have assessed the impact of lead exposure on behaviour in adolescents in South Africa or in any other African countries. Consequently this study aims to explore the association between lead exposure and socio-behavioural adjustment among young adolescents in Johannesburg, South Africa.

2. Materials and methods

2.1. Study design and sampling

The Birth to Twenty (Bt20) cohort is a uniquely South African cohort study that started in 1989 with pilot studies to test the feasibility of a long-term follow-up study of children's health and wellbeing in the Greater Johannesburg area (Yach et al., 1991). Women were enrolled in their second and third trimester of pregnancy through public health facilities and were interviewed regarding their health and social history and current circumstances. Singleton children (n = 3273) born between April and June 1990 and resident for at least 6 months after birth in the municipal area of Soweto—Johannesburg were enrolled into the birth cohort and have been followed up 16 times between birth and 20 years of age (Richter et al., 2004, 2007). Attrition over two decades has been comparatively low (30%), mostly occurring during infancy and early childhood, and approximately 2300 children and their families remain in contact with the study (Norris et al., 2007). The sample closely resembles the demographic parameters of South Africa with equal numbers of male and female participants. Assessments across multiple domains have been made of children, families, households, schools and communities during the course of the study, including growth, development, psychological adjustment, physiological functioning, genetics, school performance, and sexual and reproductive health. The Bt20 research programme, including all waves of data collection, has received clearance by the Ethics Committee on Human Subjects at the University of the Witwatersrand (M010556). The Federal Wise Assurance registration number of the Committee is FWA00000715.

2.2. Analytical study sample

Blood lead data are available for 1546 young people. No information on lead was available for the rest of the cohort due to lack of opportunities for or problems with blood sampling and sample attrition. Of these 1546 adolescents, 1041 also completed the Youth Self Report (YSR), a socio-behavioural adjustment measurement tool, at 13 years of age, 487 boys and 554 girls.

2.3. Procedures/data collection

2.3.1. Blood lead

Whole venous blood was collected into heparinised tubes determined to be free of trace metals at 13 years of age. Following preparation and centrifugation, lead concentrations in the whole blood samples were determined using an atomic absorption spectrophotometer equipped with a graphite furnace. Blood lead measurements were performed by the South African Centre for Occupational Health (now called the National Institute for Occupational Health), which participates in international and national quality control programmes for blood lead determinations.

2.3.2. Socio-behavioural adjustment

Socio-behavioural adjustment was assessed using the Youth Self Report (YSR), an adolescent adaptation of the Child Behaviour Checklist (CBCL), designed to assess children aged 11–18 years (Achenbach and Endlebrock, 1991). It consists of 112 items covering questions around mood disorders, somatic complaints, social problems, thought problems, attention problems, rule-breaking behaviour, aggressive behaviour and other problems. The YSR has been validated in several countries with cultural and language differences (Verhulst et al., 2003), but not in South Africa. However it has been used in other South African studies to assess emotional and behavioural problems (Sabet et al., 2009).

2.4. Data analysis

Historical data (demographic, maternal education, and social-economic status) collected on the cohort was utilised in the analyses. The blood lead level was the exposure variable. The average blood lead levels in the Bt20 cohort at 13 years were 5.7 μg/dl. Three percent (3%) had blood lead levels >10.0 μg/dl at 13 years. Blood lead levels were not normally distributed, and log transformed values were analysed.