The association between elevated blood lead levels and violent behavior during late adolescence: The South African Birth to Twenty Plus cohort

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\textbf{ABSTRACT}

Epidemiological studies have shown the adverse neuro-behavioral health effects of lead exposure among children, in particular. However, there is lack evidence in this regard from developing countries. The main aim of this study was to assess the association between blood lead levels (BLLs) during early adolescence and violent behavior in late adolescence.

Our study sample from the Birth to Twenty Plus cohort in Soweto-Johannesburg, South Africa included 1332 study participants (684 females). BLLs were measured using blood samples collected at age 13 years. Violent behavior was evaluated using data collected at ages 15 to 16 years using the Youth Self Report questionnaire. First, bivariate analysis was used to examine data for an association between lead exposure in early adolescence and violent behavior items during late adolescence. Principal Component Analysis (PCA) was used for dimensionality reduction and six violent behavior components were derived. Data were further analyzed for an association between BLLs at age 13 years and violent behavior using PCA derived components; to determine the specific type(s) of violent behavior associated with lead exposure.

Median whole BLLs were 5.6 μg/dL (p < 0.001). Seventy five percent of males and 50% of females had BLLs ≥ 5 μg/dL. BLLs ranging from 5 to 9.99 μg/dL were associated with physical violence (p = 0.03) and BLLs ≥ 10 μg/dL were associated physical violence and fighting (p = 0.02 and p = 0.01, respectively). When data were analyzed using continuous BLLs physical violence was associated with lead exposure (p < 0.0001). Furthermore, males were more likely to be involved in violence using a weapon (p = 0.01), physical violence (p < 0.0001), and robbing others (p < 0.05) compared to females.

The results from this study show the severe nature of violent behavior in late adolescence associated with childhood lead exposure. They highlight the urgent need for preventive measures against lead exposure among children in low or middle income countries such as South Africa.

\textbf{1. Introduction}

Lead is one of ten chemicals identified by the World Health Organization (WHO) as being of “major public health concern” and in need of action by Member States (World Health Organization, 2010). Approximately 600,000 new cases of children with intellectual disability are attributed to childhood lead exposure annually (Prüss-Ustün et al., 2011). In recent decades there has been a steady increase in epidemiological studies showing a possible link between childhood lead exposure and lower socio-economic status (Morrens et al., 2012); altered pubertal development in girls and boys (Naicker et al., 2010a; Williams et al., 2010; Den Hond et al., 2011); and intellectual impairment and antisocial behavior (Needleman et al., 1979; Needleman and Gatsonis, 1990; Needleman et al., 2002; Bellinger et al., 1992; Dietrich et al., 2001; Canfield et al., 2003; Lanphear et al., 2005; Wright et al., 2008) among others.

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Contemporary research studies involving brain-imaging show possible neuro-anatomical bases underlying the neuro-behavioral changes associated with lead exposure. In a Cincinnati Lead study, analyses of childhood lead exposure and adult brain volume using magnetic resonance imaging (MRI) showed that elevated mean childhood blood lead levels were significantly associated with 1.2% reduction of the grey matter (p < 0.001) (Cecil et al., 2008). The affected areas of the brain included prefrontal cortical areas such as the "medial and superior frontal gyri" with the "ventrolateral prefrontal cortex and anterior cingulated cortex", and in the "postcentral gyri, the inferior parietal lobule", and the cerebellar hemispheres. It is important to note that this grey matter loss was only significant among males (Cecil et al., 2008).

Childhood lead exposure has also been reported to alter the integrity of the brain, affecting executive functions and consequently resulting in neuro-behavioral changes such as violent behavior. Prefrontal cortex dysfunction is associated with aggressive and violent behavior (Brower and Price, 2001; Siever, 2008; Hawkins and Trobst, 2000; Grafman and Price, 2001; Siever, 2008; Hawkins and Trobst, 2000; Grafman et al., 1996).

In South Africa lead has been used in, among other items, petrol, paint, batteries, solder, electrical appliances, fishing weights and road markings (Mathee et al., 2009). Lead continues to be used in traditional medicines (Mathee et al., 2015), and leaded ammunition (Mathee, 2014; Mathee et al., 2017) among others. Given that South Africa has a long history of blood lead concentrations above the Centers for Disease and Control Prevention (CDC)'s recommended reference level of 5 μg/dL in children (von Schirnding et al., 1991; von Schirnding et al., 2003; Mathee et al., 2006; Naicker et al., 2010b; Mathee et al., 2013) and violent behavior characterized by physical violence, violence using a weapon, bullying, emotional violence and sexual violence during adolescence (Burton and Leoschut, 2012; Mncube and Harber, 2013), and violent behavior documented in a Cincinnati Lead study, analyses of data collected at ages 15 to 16 years (late adolescence). With these criteria, a total of 1332 study participants (684 females) comprised of 87.2% Black African and 10.4% Mixed Ancestral adolescents were included in the study. White and Indian study participants were excluded due to low numbers, 1.54% and 0.88% respectively.

2.2. Blood lead measurement

Venous samples of whole blood were collected at age 13 years into EDTA-containing tubes previously determined to be free of trace metals. Blood sampling was undertaken by professional health officials, using sterile equipment and aseptic techniques. Blood samples were vortexed and rolled on the coulter mixer for at least 10 min until properly mixed. They were diluted 10 times with 1.1% (v/v) Triton X-100 using automatic Hamilton Microlab 500 diluter into disposable 10 mL Sterilin plastic tubes covered with screw caps and mixed well using a vibration mixer. Blood lead levels were measured using Perkin Elmer 600 Aanalyst atomic absorption spectrometer with a THGA graphite furnace, Zeeman background correction and AS-800 Autosampler. Both blood samples and samples for quality control were prepared and measured in-house.

2.3. Measurement of violent behavior in late adolescence and socio-demographic factors

Data on violent behavior were collected in the 15th year data collection wave using the Youth Self Report (YSR) questionnaire. Information for the YSR questionnaire for violent behavior was collected at two time points, 11/12 and 15/16 years old. Study participants were contacted by telephone at home, work, or through nominated contactable family members or friends to secure appointment dates for data collection. Study participants came to the BT20+ data collection site and were compensated a minimum of R50 for transport. The YSR questionnaires were administered by trained field workers - most of whom have been with the cohort since its inception and have a very long trusting relationship with the study participants (Richter et al., 2004).

The YSR is a self-report questionnaire comprising 112 items assessing behavioral competency and problems of children and adolescents aged 11 to 17. It assesses aggressive and oppositional behavior attention seeking problems, as well as psychotic, impulsive, social interaction, and conduct problems among others (Achenbach, 1991). Regarding the sensitivity and specificity of the YSR questionnaire, the Achenbach System of Empirically Based Assessment (ASEBA) scales for internalizing and externalizing for YSR are 0.90 for alpha, 0.85 for test-retest reliability and 0.56 for long term stability for the United States. In general psychometric results from different cultural backgrounds have approximated those from the United States (Achenbach et al., 2008). Furthermore, YSR was used in adolescents from different cultural backgrounds.
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