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Role of fruits, grains, and seafood consumption in blood cadmium concentrations of Jamaican children with and without Autism Spectrum Disorder

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ABSTRACT

Human exposure to cadmium has adverse effects on the nervous system. Utilizing data from 110 age- and sex-matched case–control pairs (220 children) ages 2–8 years in Kingston, Jamaica, we compared the 75th percentile of blood cadmium concentrations in children with and without Autism Spectrum Disorder (ASD). In both univariable and multivariable Quantile Regression Models that controlled for potential confounding factors, we did not find any significant differences between ASD cases and typically developing (TD) controls with respect to the 75th percentile of blood cadmium concentrations ($P > 0.22$). However, we found a significantly higher 75th percentile of blood cadmium concentrations in TD Jamaican children who consumed shellfish (lobsters, crabs) ($P < 0.05$), fried plantain ($P < 0.01$), and boiled dumpling ($P < 0.01$). We also observed that children living in Jamaica have an arithmetic mean blood cadmium concentration of 0.16 μg/L which is similar to that of the children in developed countries and much lower than that of children in developing countries. Although our results do not support an association between blood cadmium concentrations and ASD, to our knowledge, this study is the first to report levels of blood cadmium in TD children as well as those with ASD in Jamaica.

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1. Introduction

Cadmium (Cd) is a metallic contaminant found naturally in the Earth's core, often as a deposit in copper, lead, and zinc ores (ATSDR, 2008). Cadmium has only one oxidative state (+2), but can form ionic complexes with both organic and inorganic complexes (ATSDR, 2008). Water-soluble forms of cadmium are highly mobile and can be ingested or absorbed by aquatic animals; however, mobility of cadmium deposited in soil is dependent on environmental conditions of the soil, such as moisture and pH, and can be inhaled when present in dust or transferred by wind (ATSDR, 2008). Cadmium has been classified as a human carcinogen (Jarup & Akesson, 2009; Nawrot et al., 2010; WHO & IARC, 1997) and has been associated with increased kidney damage (ATSDR, 2008; Jarup & Akesson, 2009; Nawrot et al., 2010), decreased lung function (ATSDR, 2008), and osteoporosis (Jarup & Akesson, 2009) in adults. Some studies have shown that it can also have adverse effects on neurodevelopment in exposed children including intellectual disabilities (Jiang, Han, & He, 1990; Marlowe, Errera, & Jacobs, 1983), decreased verbal IQ (Thatcher, Lester, McAlaster, & Horst, 1982), and learning disabilities (LD) (Capel, Pinnock, Dorrell, Williams, & Grant, 1981; Ciesielski et al., 2008). On the other hand, other studies have not reported significant associations between cadmium and neurodevelopment (Cao et al., 2009; Wright, Amarasiriwardena, Woolf, Jim, & Bellinger, 2006) or between cadmium and behavioral disorders (Szkup-Jablonska et al., 2012).

Common cadmium complexes and uses include, but are not limited to: (1) cadmium chloride, used as a pesticide, is the most toxic form of cadmium and can sometimes contaminate drinking water sources; (2) cadmium carbonate, which can be used as a pesticide and dissolves more easily in salt water; (3) cadmium oxide, used as a catalyst in electroplating and for batteries; (4) cadmium sulfate, also used in pesticides and as an intermediate for electroplating, is commonly inhaled through dust or water vapor; (5) cadmium sulfide, used as a yellow or red pigment, is the least toxic cadmium compound; and (6) cadmium stearate, which is used as a stabilizer for plastics (ATSDR, 2008; Cheng & Huang, 2006; WHO & IARC, 1997). Cadmium can be released into the air through natural processes such as volcanic eruptions, forest fires, and seawater vapor, or through human activity such as fossil fuel combustion, metal mining and refinery, waste incineration, and fertilizer/pesticide manufacture and application. As an air contaminant, cadmium can be transported and settle into surface water and soil (ATSDR, 2008). Others have identified plastic stabilizer, paint, and lacquers as sources of cadmium contaminants in farmland (Cheng & Huang, 2006). Compared with other heavy metals, cadmium in the soil can then be taken up easily by plants, introduced to humans in high concentrations, and accumulated through consumption of leafy vegetables (e.g., cabbage), root vegetables (e.g., sweet potato, yams and carrots), and grains (e.g., rice and wheat) (ATSDR, 2008; Cheng & Huang, 2007; Jarup & Akesson, 2009; Verma, George, Singh, & Singh, 2007). In addition to dietary exposure through crops, humans can also be exposed to accumulated cadmium through consumption of filter-feeding seafood, such as crabs and oysters, and beef and poultry, especially in the kidney and liver (ATSDR, 2008; Jarup & Akesson, 2009). Approximately 3–7% of ingested cadmium is absorbed through the intestines of healthy individuals, but 15–20% can be absorbed in individuals with iron deficiencies (WHO, 2011). However, up to 50% of inhaled cadmium can be absorbed (WHO & IPCS, 1992). Children are primarily exposed to cadmium through contaminated food, contaminated air, tobacco smoke, and house dust (Schoeters et al., 2006). Bioaccumulation of cadmium in the liver and kidneys starts at a young age (Schoeters et al., 2006; WHO, 2011). A longitudinal study of urinary cadmium in rural Bangladesh showed that cadmium concentrations in infants' urine was correlated with concentrations in maternal breast milk, saliva, and urine (Kippler et al., 2010). More recently, Kippler et al. (2012) reported that maternal cadmium exposure during pregnancy was inversely associated with infants' physical growth (birth weight and head circumference) (Kippler et al., 2012).

Jamaica provides a unique opportunity to study the health effects of cadmium exposure, as it has an unusually high level of this naturally occurring metal (Lalor, 2008). Concentrations in soil are ubiquitous and exceptionally high in certain parishes, with some greater than 900 mg/kg (Lalor, 2008; Wright, Rattray, Lalor, & Hanson, 2010). These levels drastically exceed the critical limits, values above which concentrations cause the soils to be considered inappropriate for any human use, which range from 0.3 to 2.0 mg/kg (Lalor, 2008). The highest levels are seen in more fertile agricultural areas near central Jamaica, allowing cadmium in soil to accumulate in crops to concentrations of up to 15 mg/kg (Lalor, 2008). Concentrations in various crops including fruits, legumes, leafy vegetables, root vegetables, and especially yams are significantly higher than those seen in other countries (Howe, Fung, Lalor, Rattray, & Vutchkov, 2005; Lalor, 2008). Thus, increased exposure in those who consume locally grown foods is a concern (Howe et al., 2005). A study conducted in Jamaica by Wright et al. (2010) showed a positive association between cadmium soil levels and urinary cadmium levels, with a 3.25 times increased risk of urinary cadmium greater than 2.5 μg/g for those in high/very high soil cadmium concentration areas compared to those in low/medium concentration areas, after adjusting for creatinine levels (Wright et al., 2010). Sediment in streams in Jamaica near soils with high cadmium levels can also have noticeable concentrations (Knight, Kaiser, Lalor, Robotham, & Witter, 1997). In addition, other studies have shown increased blood and urine levels of cadmium in people with a high dietary intake of crustaceans (e.g., lobster, crab, and shrimp), mollusks (e.g., shellfish), and other sea creatures in Britain and France (Copes, Clark, Rideout, Palaty, & Teschke, 2008; Sirot, Samieri, Volatier, & Leblanc, 2008) indicating the possibility of similar results in Jamaica where seafood consumption is also high.

Autism Spectrum Disorder (ASD) is a complicated neurodevelopmental disorders that affect communication, language development and social interaction (Genuis, 2009; Volkmar & Chawarska, 2008). Many researchers believe that the etiology of ASD involves the combination of several factors including genetic and environmental factors (Gardener, Spiegelman, & Buka, 2011; Hertz-Picciotto, 2013; Volk, Lurmann, Penfold, Hertz-Picciotto, & McConnell, 2013). While studies have shown that ASD are associated with polymorphic genetic variants (Kumar & Christian, 2009; Geschwind, 2013), many scientists