August Article of the Month

Maternal and Cord Blood Manganese Concentrations and Early Childhood Neurodevelopment among Residents near a Mining-Impacted Superfund Site

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ABSTRACT

Background:

Manganese is a trace essential element linked to the healthy functioning of the body. It aides in the formation of connective tissue, blood clotting factors, fat and carbohydrate metabolism and calcium absorption[1].

Manganese is present in food, supplements, water, soil and air. It is also found in greater concentrations in areas near mining activities, automobile exhaust and industrial manufacturing[2].

Deficiencies in manganese can be harmful to the body. Infants and children are particularly vulnerable to the effects of inadequate levels of manganese. Low levels of the essential element can impair normal brain development. It can also lead to bone malformation, infertility, seizures, and weakness[1]. However, too much manganese has neurotoxic effects in developing fetuses and children which can manifest as poor cognitive and behavioral functioning [3]. This can be detrimental to their school performance as this can impact their ability to learn and remember[1].

Much is still unknown about the differences in children's sensitivity to manganese in comparison to that of adults. Research suggests that children and newborns absorb manganese in their intestines at a higher rate than adults and are less able to readily expel it from their bodies [3]. It is also purported that children are at greater risk of overexposure to manganese because it crosses that blood-brain barrier faster in fetuses than adults.

Previous studies have evaluated the neurodevelopmental effects from manganese exposure in school-age children; however, few have studied the neurotoxic effects of prenatal manganese exposure.

Objective:

Researchers studied the link between prenatal manganese exposure and the neurodevelopment of young children who live near a former mining area and current Superfund site in Oklahoma..

Methods:

The final study population consisted of 224 mother-infant pairs who lived near the Tar Creek Superfund site in rural Oklahoma, a former lead and zinc mine. These women were identified as having given birth at the Integris Baptist Medical Center in Miami Oklahoma and having the intention to live within this study area for the next two years.

Participants were interviewed at the outset of the study to collect sociodemographic information including maternal education, race/ethnicity, and smoking and alcohol consumption during pregnancy, as well as potential exposures to metals.

Prenatal manganese exposure was determined by measuring manganese concentrations in the blood of the mother and the umbilical cord of the child at the time of birth. At two years old, the children were then given a neurodevelopment test called the Bayley Scales of Infant development to measure (cognitive function). Scores from the Mental Development Index (MDI) and the Psychomotor Development Index (PDI) were used as the primary outcomes.

The relationship between prenatal manganese blood concentrations and neurodevelopment was assessed, adjusting for potential confounding variables such as child sex, maternal education, maternal IQ, maternal hemoglobin, concentrations of maternal or cord blood lead and arsenic.

Results:

The median manganese concentration in umbilical cord blood was 43.1 µg/L, almost twice the median concentration in maternal blood which was 24.0 µg/L. Yet, only maternal manganese was significantly associated with both mental/cognitive and psychomotor development. Cord blood manganese was not significantly associated with either mental or psychomotor development.

Conclusion:

This study found that elevated manganese concentrations in the mother's blood at or near the time of delivery were associated with lower neurodevelopmental outcomes in children 2 years of age, affecting both scores on cognition and psychomotor function indices. However, there were no significant associations between manganese concentrations in umbilical cord blood and mental and psychomotor test scores.

POLICY IMPLICATIONS

This study indicates that maternal exposure to manganese can impair a child's neurodevelopment. The study's finding that maternal manganese blood concentrations are a stronger predictor of neurodevelopment than manganese concentrations in cord blood raises questions about the manner in which prenatal manganese exposures are transferred to the fetus. Placental factors and other factors that influence manganese transfer from mother to fetus are important areas of further investigation and study.

Although still much is unknown about the level of manganese that is beneficial for a developing fetus or the amount at which it becomes toxic to the neurodevelopment of a fetus, pregnant women and children need to be protected from harmful exposures to manganese.

The Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH) are two federal organizations that develop recommendations for toxic substances. While these recommendations cannot be enforced by law, raising standards of acceptable manganese blood level concentrations for infants and pregnant women is a mechanism to prompt stricter regulation of manganese that originate from pollution sources [2].

As pregnant women are at risk of exposing a developing fetus to the negative neurodevelopmental effects of manganese, it is essential that standards for manganese concentrations in workplace air are set to reflect this heightened vulnerability. The Occupational Safety and Health Administration (OSHA) is responsible for the establishment and enforcement of standards [4]. Regulations and guidelines should reflect the most recent developments in our understanding of environmental hazards.

Another important way to protect the health of women and children from overexposure to manganese is to regulate its point of introduction into the environment. In the case of this study, the elevated manganese levels present in the blood of the Ottawa County population are attributed to zinc and mining pollution. This former mining district, now known as the Tar Creek Superfund site, contains stockpiles of mine waste saturated with metals. As of 2012, manganese was found in at least 869 of the 1,699 current or former National Priorities List [2], which are priority Superfund sites identified as such because they contain uncontrollable waste [5].

In 1983, Tar Creek was designated as one of the most urgent hazardous waste sites in the Superfund site program [6]. According to the United States Environmental Protection Agency (EPA) website, in July 2010, the agency embarked on the final phase of the Tar Creek clean up. In Ottawa County, 2,887 residential yards and public properties have been cleaned up and 2.15 million tons of mine and mill wastes and contaminated soil have been removed from properties in the affected areas [7].

The Superfund program was established by the federal government in 1980 under the purview of the EPA as a way to clean up the country's most contaminated areas and as a response system to environmental disasters [8]. It provides remediation to communities impacted by industrial pollution and protects future generations of children from the deleterious effects of hazardous waste sites. Budget cuts to this program would significantly impede the cleanup process of Superfund sites and jeopardize the ability of this program to hold polluters accountable. The Superfund program must be funded in full to protect the health and well-being of children, like those in Ottawa County, who live in proximity to contaminated land.

A study conducted by EPA's Office of Solid Waste and Emergency Response examined the demographics of those who live near Superfund sites. It found that 18% of children in the United States live within 3 miles of a Superfund remedial site. This same study discovered that 45.7% of those who live within 3 miles of Superfund remedial sites are minority populations, demonstrating that proximity and exposure to Superfund sites is linked to racial, ethnic and socioeconomic inequities [9]. This finding underscores the urgent need to address environmental injustices, particularly in the formation of environmental policies and remediation strategies.

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