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Recreational Shooting & Lead Exposure in Pregnant Women

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Abstract

Lead is a known environmental toxin affecting various organ systems. Elevated blood lead levels during pregnancy are associated with gestational hypertension, low birth weight, preterm births and spontaneous pregnancy loss. Lead crosses placenta passively and causes neurodevelopmental problems in the infants. Environmental policies of the United States government has reduced lead exposure from sources like gasoline, lead based paints and lead based industries like battery recycling but lesser known sources like gun ranges and lead bullets used for hunting may serve as potential source of lead exposure. Studies have consistently shown that workers at gun ranges, law enforcement officials who practice and more importantly recreational target shooters have elevated blood levels. Lead bullets used in hunting get fragmented and consumption of game meat can also cause elevated blood lead levels. In this short review we are focusing on gun ranges and game meat hunted with lead bullets as potential sources of lead exposure. Women in reproductive age exposed to lead at gun ranges or from eating game meat hunted with lead bullets may store lead in their bones and this bone stores can serve as an endogenous source of lead during pregnancy and lactation when bone turnover rates are high. With even minimally elevated blood lead levels associated with adverse effects on pregnancy and Neuro behavioral development of the prenatally exposed infants it becomes important for women and caregivers to be aware of this potential source of lead exposure.

Keywords: Gun ranges; Recreational shooting; Hunting; Low lead level; Pregnancy effects

Abbreviations: BLL: Blood Lead Level; CDC: Centers for Disease Control and Prevention; NIOSH: The National Institute for Occupational Safety and Health; ALSPAC: Avon Longitudinal Study of Parents and Children; OSHA: Occupational Safety and Health Administration

Introduction

Lead is a naturally occurring element found in all parts of environment -air, water and soil [1] and has known toxic effects on nervous, gastrointestinal, cardiovascular, hematopoietic and reproductive systems in humans [2]. Elevated blood lead level [BLL] in pregnant women is associated with higher incidence of hypertensive disorders, preterm birth, spontaneous pregnancy loss and low birth weight births [3-5]. Lead also crosses placenta and gets deposited in brain of the fetus to cause neuro developmental problems in the infant [6,7]. Environmental policies of the government along with public awareness, and blood lead level surveillance have reduced lead toxicity from traditional sources like lead based paints, plumbing, gasoline, canned foods and lead based industries [1]. Surprisingly activities such as recreational shooting at gun ranges and hunting with lead ammunition have been identified as sources of lead exposure and have now become the focus of investigation. In this article we will review literature regarding lead exposure at gun ranges and hunting, and its risks to pregnant mothers and their babies.

Background

In 2014 almost 31% of households reported having firearms in the United States, with 9 to 14% women owning firearms [8]. There are 16,000 to 18000 gun ranges with approximately one million law enforcement officers, military veterans and around 20 million active target shooters training in them [9,10]. There are also close to 13 million recreational hunters in the country [11]. With mandatory training hours for law enforcement officials and the gun range industries projected growth in business, more women may be at risk of exposure to lead as they take part in recreational target shooting. They may also be exposed to lead dust brought by their partners from gun ranges and from hunting activities using lead bullets.

Gun range exposure to lead

National Health and Nutrition Examination Survey [NHANES] survey shows the average blood lead level of adults in the United states is 1.2µg/dl [2009-2010], but 1% of women in reproductive age group has blood lead levels more than the CDC/

NIOSH reference levels of >5μg/dl [12]. Though average national blood lead levels have dropped over the years due to stricter work place regulations, 95% of elevated blood levels (>25μg/dl) are still due to occupational exposure. Lead exerts its toxicity by forming reactive oxygen species and destroying membranes by lipid peroxidation. Elevated lead levels are associated with toxic effects on various organ systems in adults (Table 1).

Table 1: Health effects of elevated blood lead levels in adults.

Blood Lead Levels	Health Effects
10-20μg/dl	Anemia
	Possible Hypertension
20-29μg/dl	Anemia
	Possible Hypertension
	Possible kidney dysfunction
30-39μg/dl	Anemia, Non-specific symptoms*
40-79μg/dl	Non-specific symptoms*, Anemia, Hypertension, Chronic interstitial nephritis, decreased sperm count and motility, subclinical peripheral nephropathy, gout.
≥80μg/dl	Peripheral neuropathy, Encephalopathy

Adapted from Kosnet et al, Gagan Flora et al, and ATSDR [13-15].

*Non-specific symptoms: [fatigue, anorexia, constipation, arthralgia, myalgia, headache, decreased libido, sleep disturbances].

Adult Blood Lead Epidemiology and Surveillance [ABLES] is a nationwide program in the United States, conducting adult lead exposure surveillance through mandatory reporting by laboratories and doctors of elevated blood lead levels in persons aged greater than 16 years [13-15]. In 2013 federal funding for state ABLES was discontinued and in August 2015 it resumed. As of December 2015, 28 states entered into collaboration with NIOSH to conduct adult blood levels surveillance program. In a study by Beaucham and colleagues analyzing the ABLES data during 2002-2012 for elevated lead levels according to the source of exposure, a total of 2,056 persons working in police protection and recreational industries like gun ranges had elevated blood levels of >10μg/dl, 1,271 had levels of 10-24μg/dl and 785 of them had levels >25μg/dl. An additional 2,673 persons had elevated blood lead levels reported from non-work related target shooting of which 1,290 were reported with BLL >25μg/dl and 1,388 with BLLs of 10-24μg/dl [9].

International studies on exposure to lead from indoor gun ranges have consistently found higher BLL in shooting range workers as well as shooters. A cross sectional study done by Mathee et al. [16] at shooting ranges compared 87 shooters with 31 archers as control group and found that shooters had blood lead levels ranging from 2-60μg/dl with a mean of 12.8μg/dl that was four fold higher than mean blood levels of 3.5μg/dl [Range -2 to 10.4μg/dl) found in archers. Among gun shooters 84.9% had blood lead levels > 5μg/dl and 45.2% had values ≥10μg/dl and 9% had values ≥25μg/dl. A study by Madrid G et al. [17] showed shooters with >12 practice sessions per year had significantly elevated mean lead levels (mean BLL 7.6μg/dl, range 2.7-51.7μg/dl). Spontaneous pregnancy losses were reported in 24% of women whose partners had practices >12 times a year. This study brings to light possible links home lead from gun ranges on pregnant women. Also blood lead levels varied significantly by shooting site based on ventilation and lead cleaning methods. Shooters practicing at ranges, which were poorly ventilated, with dry vacuum cleaning for lead dust and no proper hand washing facilities had higher blood lead levels [17]. In another study done at indoor firing ranges by Park and colleagues [18], 27% professional shooters (mean BLL 14±8.3μg/dl), 56% of shooting range managers (13.8±11.1) and 60% of shooting range supervisors (6.4±3.4μg/dl) had elevated blood levels. This study also found that almost all sites in the firing range including beaten zones (area in trajectory of bullet) (100%), firing points (53%), waiting rooms (75%) had exceeded the permissible exposure limit (8 hour weighted average of 0.05 mg/m^3). In another study of 30 military personnel by Vivante and colleagues, the mean blood lead levels were 8.8±2μg/dL with 5 reported with levels >20μg/dL and 2 with levels >25μg/dL [19]. Workers at the gun ranges and shooters can potentially carry home lead on clothing and skin and expose pregnant women and children to lead. There are multiple case reports of children with elevated blood level found on routine surveillance where the source was traced back to a relative working in a lead based industry [20,21]. In these investigations lead was detected on work clothes, their homes and even cars. Though none of these studies and findings were in pregnant women, the threat of exposure to lead from work place can be significant.

Hunting with lead shots as a source of exposure

There are currently more than 13 million hunters in the United States. The lead bullets used in hunting have been found to disseminate into the game meat resulting in lead exposure to people who consume it regularly [22-24]. These lead particles may be so small that it is impossible to remove them all as lead bullets fragment upon impact and gets dispersed in the meat that can only be detected by radiograph. The fragmentation increases the lead availability and cooking further increases the dissemination of lead particles [25]. In a case report involving accidental ingestion of air rifle pellet by a young child, elevated blood levels up to 56μg/dL were found [26]. In March 2008 North Dakota Department of Health, Agriculture, Game and Fish recalled donated venison because of lead contamination [27]. Similar contamination was found in Minnesota and since then Minnesota, North Dakota and the Wisconsin Health Departments have advised pregnant women and children <6 years to avoid eating meat hunted with lead bullets [28]. California became the first state to implement legislation requiring non-lead ammunition for hunting by July 2019 [29].

Effects of low level lead on pregnancy

Lead is a known neurotoxin, which has been associated with adverse effects in pregnancy like gestational hypertension,

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low birth weight, spontaneous pregnancy loss and neuro developmental problems in infants even at lower levels. Due to public health awareness and environmental regulations lead levels have reduced in the United States, and in 2015, NIOSH and CDC labeled blood levels >5μg/dL as elevated levels in pregnant women. Lead is absorbed through ingestion and inhalation, redistributes to soft tissues and bone. A proportion of the absorbed lead is excreted by kidney, with small amount excreted by feces, sweat, and hair and nails [30]. Divalent metal ion transporter (DMT-1) is a protein on apical membrane of cells in the gastrointestinal tract serving as a transporter for iron and also metals like lead, manganese and cadmium. Iron deficiency up-regulates the DMT-1 receptors in the duodenum thereby increasing lead absorption [31]. Studies have also shown that increase in lead levels decrease iron and ferritin levels and iron supplementation in cases of deficiency lowers blood lead levels [19]. Lead crosses placenta [6,7] and levels in umbilical cord and maternal RBC show significant correlation and act as an in utero source of lead exposure to the fetus [32]. Lead is transferred passively in ratio of 0.7:0.9 (fetal: maternal) [5] which then in the fetus crosses the immature blood brain barrier and gets deposited leading to neuro toxicity and intellectual disabilities. Iron deficiency in pregnancy amplifies the negative association between prenatal lead exposure even at low doses of lesser than 5μg/dl (mean of 1.27μg/dL) and cognitive development in children [33]. Low dose iron supplementation may protect the integrity of blood–brain barrier against disruption by lead and reduce lead deposition in brain of fetus as observed in animal studies [34]. Even though only 1% women in reproductive age group are reported to have lead levels of >5 μg/dL, blood levels may not be the only marker of lead toxicity as 90 to 95% of lead accumulates in skeletal bone in adults [35]. Half-life of lead in blood is around 30 days, soft tissues is around 45 days and is 20-30 years in bone [36] and this bone stores of lead accumulated during reproductive years in a women, serve as an endogenous source during pregnancy and lactation when bone turnover rates are high [37,38]. Maintaining adequate levels of calcium through diet and supplementation prevents excessive turnover of bone during pregnancy and lactation [39] and serve as a preventive strategy to reduce increased blood lead exposure to fetus and infant [40]. Because of the general decline in the blood lead levels recent studies have focused on adverse effects in pregnancy associated with lower lead levels of 1-5μg/dl and 5-9μg/dl. In a large prospective ALSPAC study in UK by Taylor et al found that preterm births were increased twice and head circumference and crown heel length reduced as lead levels increased above 5μg/dL [5]. In another study by Perkins and colleagues [41] even low blood levels were associated with trend of preterm birth in male infants but no other effects were observed. The National Toxicology Program of the Department of Health and Human Services released a review of health effects of low level lead and found sufficient evidence of neuro developmental effects in infants exposed prenatally to lead like and also low birth weight births in mother with mild elevations in blood lead levels. Because of the detrimental effects of lead at very low levels to the nervous system of fetus and on infants no safe levels have been established [42] (Table 2).

Table 2: Health effects of low lead levels [2-10μg/dl] on pregnancy and fetus in utero.

Sufficient evidence	Limited evidence	Inadequate
1.Gestational hypertension 2.Reduced fetal growth and low birth weight	1. Preterm birth 2.decreased postnatal growth 3.Reduced cognitive function in prenatally exposed infants 4.ADHD and behavioral problems 5. Decreased auditory function	1. Spontaneous abortions 2. Depression, anxiety disorders in children

Adapted from *National Toxicology Program-Monograph on health effects of low level lead 2012 [42].

Conclusion

Lead is an environmental toxin associated with adverse effects on pregnancy and long-term neurological and intellectual disabilities in the fetus exposed during prenatal period. Bone lead with its long half-life serves as an endogenous source of lead during pregnancy and lactation even after exposure has been terminated which makes primary prevention of exposure to lead important in women. Women in reproductive age group should be educated about the toxic effects of lead and made aware that lead dust from target practice ranges and lead ammunition used for hunting could be a significant source of chronic lead exposure for themselves and their family. They should also be equipped with knowledge of best practices to avoid lead exposure from recreational shooting and hunting.

Recommendations

In 2002 department of health services in Alaska issued a bulletin stating that a school rifle team practicing at an indoor gun range without adequate lead control measures tested for elevated blood lead-levels and the levels reduced after the gun range maintenance was updated with lead protective measures [43]. In an investigate report of OSHA inspections it was found that from 2004 to 2013, 201 gun ranges were inspected and 1900 lead related violations of safety measures at gun ranges [44]. The NIOSH recommends series of measures to reduce work place exposure to lead at gun ranges like regular maintenance of the gun range, using wet moping technique and High Efficiency Particulate Air [HEPA] vacuums to clean the floors and surfaces, use of good ventilation with either closed system and HEPA filters or direct exhaust systems, proper education of workers, providing protective gears and medical surveillance [45]. Considering the magnitude of the problem we recommend the following measures to limit lead exposure due to target practice and lead bullets used in hunting.

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a. Recreational shooting practice should be performed in gun ranges that have been inspected and found compliant to the lead safety standards put forth by OSHA and NIOSH in the United States and by corresponding agencies worldwide.

b. Recreational shooters should be educated about the potential exposure to lead and the ways they can reduce the take home exposure such as eating or drinking in the gun ranges, using lead cleaning wipes and maintaining separate clothes and shoes for the gun ranges which should be taken in a plastic bag and washed separately.

c. Non-lead bullets can be considered at target practices and copper bullets as hunting ammunition, which doesn't fragment on impact and is nontoxic [46].

d. Though ACOG / CDC doesn't recommend routine blood lead level estimation it advises to screen high risk groups and so pregnant mothers should be asked about hobbies like recreational shooting and hunting among family members.

e. CDC recommends follow up in pregnant women with blood lead levels >5 µg/dl, to identify and eliminate the source.

f. Iron supplements should be used in cases of deficiency to reduce the toxic effects of lead in fetus.

g. Calcium intake of 2000 mg per day should be maintained through diet and supplementation to reduce bone turn over during pregnancy and lactation thereby reducing lead release from bone stores [47].

h. Pregnant women with lead levels >5µg/dl should be followed up every 2-3 months during the ante-natal period and at delivery cord blood levels should be collected to establish neonatal surveillance.

i. Chelation is not recommended with levels <45µg/dl and breast-feeding should only be discontinued with levels >40µg/dl.

j. It is advisable for pregnant women to avoid eating meat hunted using lead ammunition.

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