Title Page

**Under the Radar: Lead Exposure via Hunted Meat**

by

**Samantha Carpenter Totoni**

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Committee Page

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This essay is submitted

by

**Samantha Carpenter Totoni**

on

Select the Date

**Essay Advisor:**

James Peterson, PhD, Associate Professor, Department of Environmental and Occupational Health, Graduate School of Public Health, University of Pittsburgh

**Committee Members:**

Martha Ann Terry, PhD, Associate Professor, Department of Behavioral and Community Health Sciences, Graduate School of Public Health, University of Pittsburgh

Daniel Bain, PhD, Associate Professor, Department of Geology and Environmental Science, The Kenneth P. Dietrich School of Arts and Sciences, University of Pittsburgh

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**Abstract**

Jim Peterson, PhD

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Samantha Carpenter Totoni, MPH

University of Pittsburgh, 2020

**Abstract**

Primary prevention is a crucial strategy for addressing lead exposure, which has no safe exposure threshold. Over nine million people in the United States (U.S.) hunted wild game and upland birds in 2016; the majority used lead ammunition. Scientific evidence of an association between consumption of lead-shot meat and increased blood lead levels (BLLs) continues to build. However, the topic is omitted from lead screening protocols and lead exposure prevention information in the U.S. This omission is a matter of public health importance, ignoring not only a potential source of lead exposure for families of hunters, but also for low-income recipients of uninspected donated game meat. Consumption of lead-shot meat is also a matter of environmental reproductive justice for women who may regularly and unknowingly ingest a contaminant that becomes stored in the skeleton and is released during life events including pregnancy and lactation.

To inform education efforts about lead in hunted meat, three focus groups were conducted with deer hunters. Focus groups explored participants’ knowledge, attitudes, and beliefs about lead, their communication preferences, and their opinions about a tip sheet on lead that was produced by the Minnesota Department of Natural Resources. Across all groups, participants overwhelmingly indicated no concern about the issue of lead in hunted meat, but expressed curiosity about the topic, and responded positively to having access to a tip sheet. To improve primary prevention of lead exposure, donated game meat should be inspected for lead, questions about consumption of hunted meat should be incorporated into questionnaires used to identify people at high risk of lead exposure, and preventative information should be made more accessible to people who eat hunted meat. Preventative information should take into consideration what people in the hunting community will find to be most useful, and whom they trust to communicate that information.

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# Introduction

There is no safe threshold for lead exposure.1 The impacts of lead to human health include neurotoxicity, hematotoxicity, nephrotoxicity, cardiovascular effects, reproductive toxicity, and effects to the skeletal system.2 The skeleton is the primary site of lead storage in the body, where it represents an endogenous source of exposure, recirculating during health conditions that disproportionately affect women: pregnancy, lactation, menopause, osteoporosis, hyperthyroidism, and kidney disease. 3-7

Several studies have concluded that lead ammunition can contaminate hunted meat and that consumption of lead-hunted meat can influence blood lead levels.8-13 It is important to evaluate whether questionnaires used to identify children and pregnant women at high risk for lead exposure include the topic of hunted meat. It is also crucial to assess whether nutritional guidance for pregnant women and lead exposure prevention information for children contain information about avoiding lead-shot meat.

Hunting families are not the only people who may be exposed to lead via hunted meat. This type of exposure is also a concern for recipients of game meat donation programs in the U.S. Whether food banks inspect donated meat for lead contamination is a matter of public health importance.

There is a lack of in-depth qualitative data on hunters’ views about lead contamination of hunted meat. To address this gap and inform lead-related communication efforts for the hunting community, a series of focus groups with hunters in Pennsylvania were conducted. Recommendations for communication efforts about lead in hunted meat were developed based on hunters’ knowledge, attitudes, and beliefs, and preferences. Resulting suggested topics for communication efforts about lead in hunted meat include: Lead in Hunted Meat, Health Effects of Lead Exposure, and Improving Meat Safety.

# Background

Primary prevention of lead (Pb) exposure is critical, as there is no threshold below which lead is not considered harmful to health; blood levels above 5 micrograms/deciliter (μg/dL) are considered to be elevated.1,14 In the U.S., over nine million people hunted game and upland birds in 2016, and the majority used lead-based ammunition.15 Upon impact, the lead portion of a projectile can fragment into particles too small to see with the naked eye or sense when eating.

The U.S. Food and Drug Administration (FDA) does not set a maximum lead concentration in meat.16 However, the European Commission in Regulation set maximum levels for lead of 0.1 parts per million (ppm) for meat of livestock animals.17 Concentrations of lead over 100 times this limit have been detected in the meat of lead-shot carcasses as far as 15 cm from the entry wound. In a study of ten lead-hunted deer carcasses, the least contaminated carcass contained the following concentrations of lead in muscle tissue: 156.6 ppm at the bullet entrance; 5.1 ppm 15 cm away from the wound; 0.2 ppm at the farthest point away from the wound. The most contaminated carcass contained 476.9 ppm at the bullet entrance; 16.9 ppm 15 cm away from the bullet pathway; 0.3 ppm at the farthest point away from the wound.18 Studies have also used x-rays to visualize and count hundreds of minute lead particles in hunted meat (Table 1).

Table 1. Fragments in Hunted Carcasses Counted with the Aid of X-ray Analysis

|  |  |
| --- | --- |
| Species | Number of fragments |
| White-tailed deer (*Odocoileus virginianus)* and  mule deer (*O. hemonius)* | 213 (average)8 |
| White-tailed deer | 136 (median)9 |
| Goat-antelope chamois (*Rupicapra rupicapra)* | 135 (average)19 |
| Red Deer (*Cervus elaphus)* and Roe Deer (*Capreolus capreolus)* | 356 (average)20 |

In 2009, the Minnesota Department of Natural Resources (MDNR) published a report on lead contamination of hunted meat, comparing different types of firearms used to shoot different types of bullets into carcasses of deer and sheep.10 They found firearm type to be an important factor in lead contamination, specifically that projectiles from high-powered rifles resulted in more extensive contamination compared to shotguns or muzzleloaders. They also found variation in lead fragmentation produced by different bullet types, with soft-point bullets and rapid expanding ballistic tip bullets fragmenting the most. For example, on average, Nosler Ballistic Tip lead rifle ammunition produced 16 times the number of lead fragments in a carcass compared to the Winchester XP3 lead rifle ammunition. The authors found that approximately 30% of the lead microparticles left behind in the animal’s body were within two inches of the exit wound. Lead fragments were detected up to 18 inches from exit wounds (the maximum distance that could be measured with x-ray). Other important findings from the report included the observation that the common practice of rinsing a carcass tends to reduce lead around the wound channel, but it also transports lead away from the wound. In addition, a shot to the hindquarters of a deer where heavy bones are found resulted in so much fragmentation “…that a hunter would likely not want to utilize this meat as there would be no way to remove all the fragments.”10 Based on the findings of this report, MDNR produced a tip sheet for hunters about avoiding lead exposure via hunted meat (Appendix).

## Lead Exposure in the Context of Lead Ammunition

In the context of lead ammunition, individuals can be exposed to lead via inhalation, dermal absorption, and ingestion.2 Consumption of lead-shot meat has been observed to increase blood lead levels.9,21 The skeleton is the primary site of lead storage in the body, and increased stores of lead in the skeleton may disproportionately impact women. 3-7

### Routes of Exposure

Inhaling airborne lead from gun smoke produced by a firearm is a widely recognized risk factor for lead exposure. For example, the U.S. Occupational Safety and Health Administration (OSHA) Lead Standard enforces standards in workplaces with potential airborne lead exposure, such as indoor shooting ranges. Employers are required to determine the concentration of airborne lead in relation to a recognized action level and permissible exposure limit for lead.22 Approximately 95% of inhaled lead particles <1 μm can are deposited in the alveoli and absorbed into the blood. Particles > 2.5 μm are deposited in ciliated airways, transferred by mucociliary transport into the esophagus and swallowed. 23

Dermal absorption of inorganic lead is an inefficient means of exposure. However, hand-to-mouth behavior when dermal lead is present may result in exposure via ingestion.4

In 1979, oral ingestion of metallic lead particles was shown to influence blood lead levels in a study conducted with rats.24 Following ingestion, lead is primarily absorbed in the duodenum.25 The proportion of lead absorbed depends on many factors including age, diet, nutrition, and characteristics of the ingested lead. Adults may absorb up to 20% of ingested inorganic lead after a meal and 60-80% with an empty stomach, while children absorb approximately 50% of ingested lead after a meal and up to 100% with an empty stomach.4

In physiological systems, lead is a divalent cation, meaning it is missing two electrons as compared with the neutral atom. This characteristic is shared by essential elements such as calcium, iron, and zinc. This similarity allows lead to be incorporated into membrane transport systems that facilitate absorption from the intestine through cell membranes in the body. Competition for the same transporters in the gastrointestinal tract results in an inverse relationship between high levels of dietary calcium or iron and blood lead concentration. Conversely, a dietary deficiency in calcium or iron enhances lead absorption.3

Another important factor in gastrointestinal absorption of lead is the size of the ingested particles. In rats, an inverse relationship was found between absorption and particle size. The concentration of lead in tissues was 2.3-fold higher when rats ingested an acute dose of particles <38μm in diameter compared to the same dose of particles with diameters in the range of 150–250 μm.24 The majority of lead particles in lead-hunted meat have been found to be invisible to the naked eye.8

Several studies have investigated whether consumption of lead-hunted meat can influence blood lead levels. Hunt et al. fed lead-hunted deer meat to pigs and observed increasing blood-lead concentrations within days, stating, “We conclude that people risk exposure to bioavailable lead from bullet fragments when they eat venison from deer killed with standard lead-based rifle bullets and processed under normal procedures. At risk in the U.S. are some ten million hunters, their families, and low-income beneficiaries of venison donations.”9 (Pg 1)  Juric et al. estimated dietary exposure to lead among indigenous people living on-reserve in Ontario, Canada. The findings suggested that even though traditional foods such as moose and deer meat provided 1.8% of calories, they were the source of 73% of dietary lead intake: “These results indicate that consumption of foods hunted with Pb containing ammunition and shot puts the population at elevated risk of Pb toxicity.”11 (Pg 55)

Liberda et al. evaluated blood lead levels in the Cree Nations of the James and Hudson Bay regions of Quebec, Canada, where traditional foods included moose, bear, caribou, and waterfowl, and concluded, “…both hunting with lead ammunition and consumption of hunted wildlife continue to present signiﬁcant sources of lead constitute important ﬁndings that require exposure reduction strategies, a call echoed by others.”*12* (Pg 409)

Buenz et al. reported on a subsistence hunter of deer and feral goats in New Zealand whose blood lead levels were 74.7 ug/dL. Lead was detected in the meat the hunter harvested. After switching to non-lead bullets, the hunter’s blood lead levels began to decrease dramatically. The authors concluded, “Unsafe blood lead levels can occur from eating game harvested with lead ammunition. Physicians should warn hunting patients of this potential risk and counsel them about the availability of nonlead ammunition alternatives.”*13* (Pg 181)

Following absorption, the half-life of lead in red blood cells is approximately 30 days.26 As a result, blood lead levels can be deceivingly low months after peak consumption of lead-hunted meat. For example, a study in Greenland identified a clear seasonal variation in blood lead levels, with peaks during the months when consumption of hunted meat was highest, and decreases during months of lower consumption.21

No study has been conducted in the U.S. to understand monthly patterns of blood lead levels among people who eat lead-hunted meat. Yet the National Shooting Sports Foundation states, “A study from 2008 by the U.S. Centers for Disease Control and Prevention (CDC) on blood lead levels of North Dakota hunters confirmed that consuming game harvested with traditional ammunition does not pose a human health risk.”27 However, the referenced study collected blood samples five months after the hunting season, and reported results for people who ate wild game in general. It was not determined whether the meat was hunted with archery, non-lead ammunition, or lead ammunition. A significant difference of 0.30 μg/dL was observed between the average concentration of lead in the blood of people who reported eating wild game compared to those who did not.28

### Storage and excretion

Even when lead is no longer detectable in blood, it has not necessarily left the body. The skeleton is the primary site of the lead body burden, containing approximately 95% of lead in adults and 75% in children.4 Lead is deposited during the process of bone calcification, and forms a highly stable phosphate salt called hydroxyapatite, the primary crystalline matrix of bone.

Lead can remain in bone for decades; residence time is strongly influenced by bone porosity. Bones in the human skeleton contain cortical and trabecular tissue. Cortical tissue is dense, with approximately 30% of its volume occupied by marrow and vascular space. The clearance half-time of lead in cortical tissue is decades. Trabecular tissue consists of a network of rods (trabeculae) and marrow-vascular spaces; as a result, porosity can be as high as 90%. Clearance half-time of lead in trabecular tissue can be years to decades.3,29

The lead that builds up in the skeleton over decades is not inert; it represents an endogenous source of lead exposure, with the capability to be redistributed in the bloodstream. Most conditions that cause the release of lead back into the bloodstream disproportionately affect women: pregnancy, lactation, menopause, osteoporosis, hyperthyroidism, and kidney disease. Other lead-releasing conditions are calcium deficiency, physiologic stress, and broken bones. 3-7

Despite the central role of bone in models of lead metabolism, the basic kinetics of bone lead are not well understood. In the early 1990s, the most frequently used models of lead kinetics were evaluated using longitudinal studies of lead in blood and bone of occupationally exposed workers. The models assumed first-order kinetics: that the half-life of lead in bone is completely independent of lead concentration in the bone tissue itself. However, after the epidemiological data were applied, these models required significant adjustments. As Brito et al. described, “Observational results from occupational populations imply that current models of human lead metabolism should be examined with a view to making adjustments to account for kinetic rates which vary with exposure level and/or age.”30 (Pg 87) The authors put forward hypotheses to explain the observed behavior of lead, including that the intensity of lead exposure and/or age may influence significant changes in bone turnover. Indeed, formation of new bone may be delayed by higher bone lead concentrations, causing lead to remain in bone longer.31 In 2015, when a standard model of lead kinetics was tested for applicability to humans with histories of low, chronic lead exposure, the authors found the model did not simulate observed patterns in trabecular bone lead concentration or reproduce measured lead distributions in individuals.32

In terms of excretion, inorganic lead such as that found in lead ammunition is cleared by the kidneys and does not pass through the liver to enter the feces via bile (organic lead compounds are metabolized in the liver and excreted primarily in the feces). Excretion of lead also occurs via breastmilk.33

## Health Effects of Lead Exposure

The similar valence chemistry between lead, calcium, zinc, and iron enables lead to take over the role of those essential elements in several systems, disrupting tightly regulated homeostatic processes, and leading to toxicity in the nervous system, kidneys, reproductive system, and immune system.3

### Neurotoxicity

Neurotoxicity of lead impacts both the developing brain and the adult brain and can result in peripheral neuronal effects. Lead enters the brain through the blood-brain barrier (BBB) and blood-cerebrospinal fluid (CSF). Accumulation of lead in cells of the BBB and CSF results in altered cellular calcium homeostasis and signaling.34

### Damage to the adult brain

In the adult brain, blood lead levels from 40 to 120 μg/dL have been associated with neurobehavioral effects including irritability, fatigue, dizziness, and decreased libido. Psychiatric effects impacting reaction time, hand dexterity, cognitive performance, nervousness, and coping ability have been associated with blood lead levels of 50–80 μ g/dL. Encephalopathy occurs in adults following extremely high lead exposure, with blood lead levels reaching over 400 μ g/dL. Lead exposure was associated with greater levels of conflict in interpersonal relationships among workers occupationally exposed to lead compared to those who were unexposed. Mice exposed to lead in early life have been found to exhibit enhanced expression of the Alzheimer’s Disease-associated protein tau.2

### Damage to the Developing Brain

The developing brain is much more susceptible to the effects of lead than the adult brain. In addition to the tendency for children to absorb a larger fraction of lead from their GI tract, developing brains exhibit a wider range of activities for lead to disrupt, such as neuron migration and synapse pruning and trimming. The interference of lead in these and other processes results in incomplete connections between structures, leading to functional deficits. Lead can also prevent the bodies of growing children from absorbing minerals essential to proper brain and nerve development such as iron, zinc and calcium.

There is no blood lead level without risk of poor developmental or intellectual function in developing brains, and a lack of overt symptoms does not equate to a lack of adverse impact. While encephalopathy in children has been observed with blood lead levels between 60–300 μ g/dL, adverse health effects occur in children at BLLs <5 μg/dL. These include attention-related behavioral problems, decreased cognitive performance, and greater incidence of problem behaviors. Children often do not exhibit signs of lead toxicity until elementary through middle school, as academic demands intensify.2

In utero exposures to lead as early as the first trimester of pregnancy have been associated with decreased intelligence scores, and lead exposure during infancy and childhood continues to impact IQ.35,36 Canfield et al. tested blood lead levels every six months in children six-60 months of age, and administered the Stanford–Binet Intelligence Scale at the ages of three and five years. They found that children with blood lead levels of 10 ug/dL had IQs 7.4 points lower than children with levels of 1 micrograms/deciliter. When blood lead levels further increased from 10 to 30 micrograms/deciliter, intelligence dropped by an additional 2.4 IQ points. Areas of intelligence that have shown decrements due to lead exposure include fine motor skills, attention, arithmetic skills, reading skills, nonverbal reasoning, reaction time, visual-motor integration, and short-term memory. Lead exposure has also been linked to antisocial behavior in school children. For instance, children in the Pittsburgh, Pennsylvania, school system were found to have bone lead levels associated with aggression, delinquency, and arrest and adjudication as a delinquent in the juvenile court system.37

Evidence suggests that the developing brains of males and females differ in susceptibility to lead exposure. Some studies have found prenatal lead concentrations to be inversely associated with cognitive scores and attention scores in males but not females.38,39 This may be due to the neuroprotective action of estrogen and estradiol for the developing brains of females but not males. However, timing of lead exposure may also play an important role. Joo et al. found that lead levels during late pregnancy were significantly associated with increased risk of behavioral problems in males, while lead levels in 2- and 5-year-old children's blood significantly increased behavioral risks in females.40

### Damage to the Peripheral Nervous System

Among peripheral nerves, motor neurons are most susceptible to lead. Peripheral neuropathy resulting from lead exposure was first identified in house painters and other lead workers; manifestations included foot drop and wrist drop. Additional symptoms, measured in workers from a battery recycling plant, include extensor weakness of the distal upper limbs and weakness in dorsiflexion of the foot. Damage to children’s peripheral nerves occurs at blood lead levels similar to that of adults (20–30 μ g/dL). Although the effects of lead on peripheral nerves may fall within the range of normal variation and may not be clinically significant for a particular individual, they are significant when viewed over a population.2

### Hematotoxicity

Lead inhibits the synthesis of heme, an essential co-factor for many biological processes including oxygen transport and storage, electron transfer, and drug and steroid metabolism. Approximately 80 % of lead in red blood cells is bound to the metalloenzyme 5-aminolaevulinic acid dehydratase (ALAD). ALAD utilizes zinc to perform the first step in the production of heme. Lead ions displace the zinc ions, making the ALAD inactive. This process blocks formation of new heme groups and is responsible for the development of anemia in lead-exposed humans at levels < 10 μg/dL.2

### Nephrotoxicity

Both chronic and acute lead exposure can produce renal dysfunction. Low-level chronic lead exposure has been associated with decreased kidney function and chronic kidney disease.41 Acute lead-induced nephropathy is characterized by Fanconi syndrome, a generalized deficit in tubular transport. Fanconi syndrome allows for the transport of glucose, amino acids, uric acid, phosphate, and bicarbonate into the urine rather than being reabsorbed. The loss of phosphates results in osteomalacia (bone demineralization), releasing more lead into circulation, exacerbating kidney damage.2

### Cardiovascular Effects

Lead exposure also has effects on the cardiovascular system. Experimental studies in animals have found that chronic exposure to low lead levels causes arterial hypertension that persists long after the cessation of exposure. Seven reviews and meta-analyses from 1987 to 2006, combining data from more than 30 original studies and approximately 60,000 participants, have examined the evidence relating blood lead to blood pressure. All seven reviews concluded that there was a positive association between blood lead levels and blood pressure.42

Obeng-Gyasi et al. evaluated cardiovascular-related clinical markers in a cross-sectional study of United States adults. Results suggested that lead exposure has a profound effect on the cardiovascular system; all levels of exposure were associated with potentially adverse outcomes.43 Lanphear et al. estimated the contribution of blood lead levels in the U.S. to the number of deaths from all causes and from cardiovascular disease in a nationally representative sample. The authors concluded, “…concentrations of lead in blood lower than 5 μg/dL (<0·24 μmol/L) are an important, but largely ignored, risk factor for death in the USA, particularly from cardiovascular disease.”44 (Pg 177) They also suggested that any comprehensive strategy to prevent deaths from cardiovascular disease should include efforts to reduce lead exposure.

### Reproductive Toxicity

Lead is a strong spermicidal agent; blood lead levels >40 μ g/100 mL in men are associated with low semen volume and sperm counts, increased abnormal sperm morphology, and decreased sperm motility.2

Due to hormonal changes during pregnancy, lead that has been stored in the skeleton is released into the blood, exposing both mother and fetus. As a result, high levels of lead in mothers’ bones have been identified as a risk factor for impaired mental development in infants.45 In addition to neurotoxic effects, potential consequences to the fetus or infant include low birthweight and spontaneous abortion.46,47

In a prospective study, Borja-Aburto et al. found the odds of a spontaneous abortion nearly doubled for each 5 μg/dL increase in the pregnant woman’s blood lead.48 Lead is also a major risk factor for preeclampsia, a high-blood pressure condition that can have severe consequences for the mother and infant.49 Women who experience adverse pregnancy outcomes such as preeclampsia face increased risk of cardiovascular and metabolic diseases as they age.50

### Effects on the Skeletal System

Adult lead exposure has been correlated with osteoporosis, delayed fracture healing and osteoarthritis. Sun et al. found a dose–response relationship between lead exposure and prevalence of osteoporosis among an occupationally-exposed population in a battery plant.51 Lead inhibits osteoclast and osteoblast bone cells, which drive the continuous resorption and rebuilding of the human skeleton, typically at an annual rate of 1 – 8%. Lead exposure creates an imbalanced resorption-rebuilding process that results in bone loss and bone tissue deterioration, both characteristic of osteoporosis. Lead may interact with other processes during the course of osteoporosis to worsen the effects of the disease. Lead has also been found to negatively impact cartilage and has been identified as an environmental risk factor for osteoarthritis, a poorly understood disease with no effective disease-modifying treatments currently available. Statistically significant increases in prevalence and severity measures for radiographically confirmed knee osteoarthritis have been observed with increasing levels of blood lead.52

## Lack of Attention to Lead-hunted Meat in Screening Practices

The American College of Obstetricians and Gynecologists (ACOG) recommends that doctors ask women a series of questions to identify whether they are at risk for elevated lead exposure, and if one risk factor is identified, to perform a blood lead test. Consumption of hunted meat is not included in any of ACOG’s 12 recognized risk factors.53 Similarly, questions relating to consumption of lead-shot meat are absent from the CDC’s Guidelines for the identification and management of lead exposure in pregnant and lactating women.54 Advice about minimizing exposure to lead in hunted meat is also absent from ACOG’s nutritional advice for pregnant women.55

Childhood prevention information related to hunted meat is absent from the American Academy of Pediatrics, the CDC, Environmental Protection Agency (EPA), and guidance from state health departments, including the Pennsylvania Department of Health.56-59 Although the New York Department of Health issued the following statement: “…people who eat game harvested with lead shot may be exposed to lead. This is of greatest concern for young children because they are particularly susceptible to the toxic effects of lead,” the topic is absent from the Department’s advice on childhood lead poisoning prevention.60,61 The Wisconsin Department of Health Services acknowledges concerns about lead exposure from eating hunted meat and recommends use of non-lead ammunition. However, the topic is absent from the department’s lead prevention information, ‘Feeding Your Child.’ 62,63

The most common policy in the U.S. is for children to have their blood lead levels tested by the age of two, before they are likely to consume large amounts of hunted meat. However, blood lead levels of six-year-olds have been more strongly associated with impaired cognitive and behavioral development compared to blood lead levels measured earlier in childhood.64 This highlights the importance of questionnaires for identifying older children at high risk of lead exposure, and the need for a question about consuming hunted meat.

## Lack of Lead Inspection in Food Banks

Venison donation programs have provided millions of meals to food banks across the country. States with venison donation programs include those that also harvest the most deer: Texas, Michigan, Pennsylvania, Wisconsin, and Georgia.15 None of these five states requires x-ray inspection of meat for lead contamination.65-69

In 2008, the U.S. Department of Health and Human Services analyzed nearly 200 packages of venison from food pantries in Wisconsin (it is unknown how many packages contained meat that was hunted with firearms). Lead was detected in 15% of packages; the average level in lead contaminated meat was 160 ppm. At this concentration of lead, the study predicted 81% of children who consumed just two meals of venison per month would experience blood lead levels above 10 ug/dL.70

Among other states, Minnesota requires x-ray inspection due to documented lead contamination of donated venison.71 However, North Dakota and Iowa currently accept venison donations to food banks without lead inspection, despite previous findings of lead contamination. The Iowa Department of Public Health has previously responded to this issue, pointing out that no cases of concerning blood lead levels in the state’s children have ever been attributed to lead in venison.72 However, this fails to recognize that most children tested in Iowa’s program are tested from ages 0-3.73 This also fails to take into consideration that blood-lead levels tested several months after the hunting season may be deceptively low.

# Methods

If information about lead-contamination of hunted meat is to reach hunters and have potential to influence their knowledge and behavior, it must be relevant and meaningfully address their questions and concerns. Development of appropriate and effective communication should be based on an in-depth understanding of current knowledge, attitudes, perceptions, and beliefs as well as communication preferences.74 However, in-depth qualitative data on hunters’ views on this topic are limited. To address this gap and inform lead-related communication efforts in the hunting community, we conducted a series of focus groups with hunters in Pennsylvania. The aim was to collect data on hunters’ knowledge, attitudes, and beliefs regarding lead in hunted meat and to explore their communication preferences for topics and sources of lead-related information.

Participants were recruited through newspaper advertisements and were considered for participation if they were a hunter over the age of 18. The project received an exemption from human subjects review.

Individuals were offered a monetary incentive for their participation; participants received a $25 gift card from Dick’s Sporting Goods. At the beginning of each focus group session, participants were informed about the intention for using recorded data in a research project and given assurance of confidentiality. Each focus group session was audio recorded and transcribed. During the focus group, participants were provided with a tip sheet about lead and hunted meat developed by the Minnesota Department of Natural Resources (see Appendix).

The facilitator asked the following questions: 1) What is important to you when you are deciding whether your hunted meat is safe to eat? 2) What have you heard about the health effects of lead? 3) Can you tell me your thoughts on lead in deer meat? 4) What sources of information do you trust the most to learn about lead in deer meat? 5) What would you like to know more about in terms of potential health consequences of consuming lead in deer meat? 6) What do you like/don’t you like about the example tip sheet? What would you change?

A thematic analysis was conducted on each question using NVIVO software.

# Results

Three focus groups were conducted with deer hunters from May through July 2019 in Huntingdon (FG-H), Mercer (FG-M), and Westmoreland (FG-W) counties in Pennsylvania. Focus groups were held in reserved meeting rooms of public libraries. Participants numbered five in FG-H, six in FG-W, and ten in FG-M. Each focus group was conducted by a trained facilitator and assisted by a note taker. The duration of each focus group was approximately 90 minutes. Data analysis proceeded based on themes determined by the questions. These include Meat Safety, Health Effects, Views on Lead in Meat, Trusted Information Sources, Questions, and Tip Sheet Feedback. Data from themes were incorporated into suggested points of communication about lead exposure via hunted meat.

## Meat Safety

Hunters consistently identified safety issues with meat that can be identified by sight, smell and knowledge of the outdoor temperature. Examples include visible infections or blood clots, unusual smells, and the recognition that a carcass had been sitting in warm temperatures for a long period of time.

*So if the appearance of the meat and the smell of meat seems to be normal and the temperature- like you wouldn't pick up a roadkill today to eat, but you know in the wintertime you would. You can tell by the smell and the look if it's fresh enough* (FG-W).

Some participants mentioned that meat damaged by lead bullets may be more likely to be made into ground meat. This is consistent with findings that ground venison is more frequently contaminated than other cuts of hunted meat.

*…but somebody that hits one in the backside, you know, they're going to grind a lot of that meat up, they're not going to get the steaks out of it. So, they're going to grind a lot of mess, there's more of a chance of that meat having some of this lead contamination to it* (FG-W).

*And there's some people that just don't really think about it. They just grind it all up. They think, 'Eh, just more meat, it'll get grinded it up. I'm going to cook it anyway. So it'll be fine* (FG-M)*.*

## Health Effects

Participants reported having heard that lead affects the brain, but only at very high exposures. Participants also heard that children are especially susceptible to the effects of lead, and reported not hearing anything about risks to adults.

*…I do take lead exposure seriously. I've seen what different things can do to children and infants. I do have to say that I know lead is harmful. You know, and I don't want to be ignorant about it. But you better drink a whole cup full. You really need to have a lot of lead exposure* (FG-H).

*And kids are uh - way more - what do I want to say, more susceptible? I mean, it's more dangerous for a kid than a dog. That's all I ever heard* (FG-H)*.*

*As far as an adult, I've never really heard that much about danger* (FG-W).

## Views on Lead in Meat

Participants consistently reported not being concerned about lead exposure through lead-shot meat, and reported associating the topic with anti-hunting or anti-gun groups.

*Am I as a hunter, concerned about lead poisoning from ammunition being in any of my meat? Absolutely not* (FG-H).

*A lot of times when I've seen that, it's coming from animal rights groups. They're against hunting* (FG-M).

*But you have anti-hunters out there. So all these situations that you're talking about now is going to come from them. Or people like that. Okay?* (FG-M).

Participants mentioned having large supplies of lead ammunition they intend to use

*I mean, I probably have enough shot shells to last me for the rest of my life in my house, so even if they come up with the other ones, I’m still gonna have the ability to finish using what I have* (FG-H)*.*

*I have enough bullets loaded that I'll never, never need to load a bullet as long as I live* (FG-W)*.*

*And you know what, let's be honest too. If they said I had to change over tomorrow, I'd say 'okay'. And I would still be shooting my lead.*

*Yep.*

*Because I have so much of it* (FG-M).

## **Trusted Information Sources**

Participants consistently indicated a lack of trust about information coming from the Pennsylvania State Game Commission. The CDC was also mentioned as having a perceived anti-gun agenda. Sources of information hunters reported that they would trust include are listed below:

* Other hunters
* Department of Health
* American Medical Association
* United States Department of Agriculture (USDA)
* Pennsylvania Department of Natural Resources (DNR)
* Penn State Extension

*Not the Game Commission. That's for sure* (FG-W).

*At least it wasn't Game Commission. They're prejudiced.*

*They are, they are. I don't trust them any further than can throw 'em. At one time I did* (FG-H).

*Certainly not the CDC. Certainly not them. They have agendas of their own. They're, they're, you look at it -they're even thinking that, shootings are a disease to be controlled, so I will not trust them. At all. At all* (FG-W).

*Yeah. Most of the information comes from hunters, I would say. Like us getting together and talking* (FG-H).

**4.5 Participants’ Questions**

In the course of the focus groups, participants asked a number of questions on the topics of ammunition**,** lead exposure via hunted meat, lead fragmentation in hunted meat, health effects of lead exposure, and addressing lead exposure.  
Ammunition

* Is there a safer, cheaper, better alternative to lead ammunition?
* Are there health risks to using copper-based ammunition?
* If I use an alternative to lead ammunition, what will it do to my rifle?
* How much lead is inside commonly used bullets?

Related to the question of the lead content of bullets, all participants in one focus group (FG-W) agreed that they did not realize their ammunition contained lead when they first started hunting as youth

*“I didn't even really- growing it up I never even knew- I just thought a bullet was a bullet. I didn't know it was lead and all that stuff.”*

*“No you just knew it was a bullet.”*

*“That's right.”*

*“Yeah, and we just shot it.”*

*“Yeah.”*

*“Yeah.”*

*“Right.”*

*“Right.”*

*“Exactly. I didn't even notice the split shots were harmful till I got older.”*

Lead Exposure via hunted meat

* How does hunting-related lead exposure compare to the other ways I am exposed to lead?
* What are acceptable levels of lead in hunted meat?
* What amount of lead has been found in hunted meat?
* Do pieces of lead come off a bullet when it hits a bone?
* Would I realize it if I’m chewing lead?

Lead fragmentation in hunted meat

* If a bullet passes through a deer without hitting a bone, could there still be lead in the meat?
* Is lead contamination of a carcass found right at the wound, or throughout the carcass?
* Have there been any studies about lead content or wild game?
* Can I avoid eating lead fragments in hunted meat?

Heath effects of lead exposure

* Are small particles of lead that I can’t feel when I chew really harmful?
* How much lead can I be exposed to without experiencing health effects?
* Does lead build-up in human bodies?
* Would ingested lead fragments stay in my body long enough to be absorbed?
* How long does it take for lead to dissipate from the body?
* How much lead exposure does it take to produce health effects?
* What are potential health effects be of lead exposure?
* Are there health risks to people other than pregnant women and children?
* Do the effects of lead exposure happen right away or years down the road?
* What are the symptoms of lead exposure?

Addressing lead exposure

* What should I do if I have symptoms of lead exposure?
* Is there a test for lead levels in humans?
* Will blood tests for lead reveal lead exposure from a long time ago?

**4.6 Tip Sheet Feedback**

Participants generally expressed a positive response to having a tip sheet available, and specifically expressed the following:

* Interest in learning about physiological effects of lead;
* Interest in warnings about excessive shot damage resulting in widespread lead contamination;
* Interest in advice about lead contamination resulting from rifle compared to a shotgun;
* Interest in advice about how ammunition type may influence lead contamination; and
* Confusion about the following statement on the tip sheet: “Lead in venison has not been linked to any illnesses.”

*Well, this was the sentence that caught my attention is number three, there. ‘Lead can have the physiological effects on human bodies and brains at levels below that which would cause any noticeable signs of sickness.’ So it can affect you without you knowing* (FG-W).

Participants suggested making the following changes to tip sheet:

* Adding information about health effects to children and adults
* Adding specific information regarding:
  + The amount of lead considered to be too much lead in meat
  + The amount of lead that has been found in lead-shot meat
  + More details about lead contamination from a rifle compared to a shotgun

*Give some statistics of what it might cause or what it might do, then maybe they're going to pay a little bit more attention to what's here. Okay, but (referring to the tip sheet) they're escaping the, they're not attaching the disease to this. They're leaving the medical end out of it. Okay, and that can influence a person, whether they do these rules or not or if they just say 'Oh lead contamination. What the hell is lead contamination. Phsshhh.’* (FG-M)

# Discussion

These results can aid the direction of communication efforts about lead exposure via hunted meat, including efforts of health departments, natural resources departments, and wildlife management agencies. Although participants reported not being concerned about the topic of lead in hunted meat, they expressed interest and curiosity about the topic. Participants also indicated a desire to have accessible information to aid in decision making about use of lead ammunition. The trusted sources mentioned by participants included the American Medical Association and Health Departments. Therefore, it is likely that physicians, including pediatricians and obstetricians, are likely to be effective messengers of preventative information. Participants also provided valuable suggestions for the content of information about this topic for hunters.  Although information about lead contamination of hunted meat was viewed as useful, participants indicated that without detailed information about the potential health effects of lead exposure, it is difficult to make a decision about using lead ammunition.

The language that is used to communicate about lead exposure via hunted meat may contribute to a lack of concern about this topic. Among participants, there was a widespread belief that if there are no visible pieces of lead, then lead is not present. This may be influenced by the term commonly used to communicate about this topic, “lead fragmentation”, which implies that the lead in a contaminated carcass will be visible and avoidable. A related perception among participants was that shotguns cause greater lead contamination than rifles; research has found the opposite.10 This misperception is likely because shotguns are more likely to leave large, visible pieces of lead in the meat compared with rifles. A term such as “lead contamination” may be more useful in communication efforts, as it does not imply a size of lead. In addition, use of the term “lead poisoning” without defining the associated health effects may influence the belief that the only health impacts of lead exposure to be concerned about are those related to extremely high, acute lead exposures rather than chronic, low-level exposures to lead.

Another possible contributor to a lack of concern about this topic is a lack of communication about potential health effects of low-level lead exposure to adults. This may explain why participants reported hearing only about potential health effects to children. Some potential health effects, such as cardiovascular disease, may impact both men and women. Others, such as increased risk of spontaneous abortion and preeclampsia are threats specific to women’s reproductive health. The concept of environmental reproductive justice, which pertains to ensuring that a community’s reproductive capabilities are not inhibited by environmental contamination, and has recently been recognized in environmental health literature.75 When advice about consuming lead-shot meat does recognize the risks to pregnant women (see Appendix), it is presented in the context of women avoiding consumption of lead during pregnancy. The risks that skeletal stores of lead from chronic lead exposure may pose to women’s reproductive health are left unaddressed. As a result, the potential benefits to avoiding lead exposure in the decades preceding pregnancy are not conveyed.

## 5.1 Recommended topics for communication about lead exposure via hunted meat

Based on scientific findings about lead exposure via hunted meat, the health effects of lead, and the data collected from the focus groups in this study, it is recommended that messages about lead in hunted meat include the following topics: Lead in Hunted Meat, Health Effects of Lead Exposure, and Improving Meat Safety. An example of content for communication about lead exposure via hunted meat is provided in sections 5.1.1-5.1.3.

### Lead in Hunted Meat

* Most ammunition used for hunting game and upland birds in the U.S. contains lead. Lead-based ammunition can contaminate hunted meat and has been detected more than 18 inches away from the wound channel. Scientists have found the levels of lead in hunted meat can be hundreds of times higher than accepted levels of lead in the meat of livestock (0.1 parts per billion).
* Lead contamination in hunted meat is typically too small to see with the naked eye or feel when chewing.
* Ammunition from rifles have been found to cause more lead contamination in carcasses compared to ammunition from shotguns and muzzleloaders.
* A poorly placed shot that hits the bones of an animal is likely to result in extensive contamination throughout the carcass. However, broad contamination can occur even if no bones are struck.
* For more information, see the following study conducted by the Minnesota Department of Natural Resources: <https://www.dnr.state.mn.us/hunting/ammo/lead.html>

### Health Effects of Lead

* Studies have found that eating lead-contaminated meat can increase blood lead levels during the months of meat consumption.
* No amount of lead in the blood is considered to be safe. Although extremely severe impacts to the brains of children may occur at very high blood lead levels (60-300 μg/dL), even blood lead levels below 5 μg/dL in children have been associated with attention-related behavioral problems, decreased cognitive performance, and greater incidence of problem behaviors.
* Long-term, low levels of lead exposure in adults may result in a wide array of potential health effects following years or decades of exposure. This includes high blood pressure, cardiovascular disease, and kidney disease.
* Lead may impact the outcome of pregnancy, including increasing the risk of spontaneous abortion and a serious high blood pressure condition called preeclampsia.
* Consumption of lead-contaminated meat prior to pregnancy, as well as during pregnancy, may impact pregnancy outcomes. This is because a portion of ingested lead from each contaminated meal is stored in the skeleton, where it can build up for decades. This stored lead is released during pregnancy.
* Blood lead tests can be requested by healthcare providers. Blood lead levels may be deceptively low during months of little or no consumption of hunted meat, except for pregnant women or people with health conditions such as hyperthyroidism, osteoporosis, and kidney disease.

### Improving Meat Safety

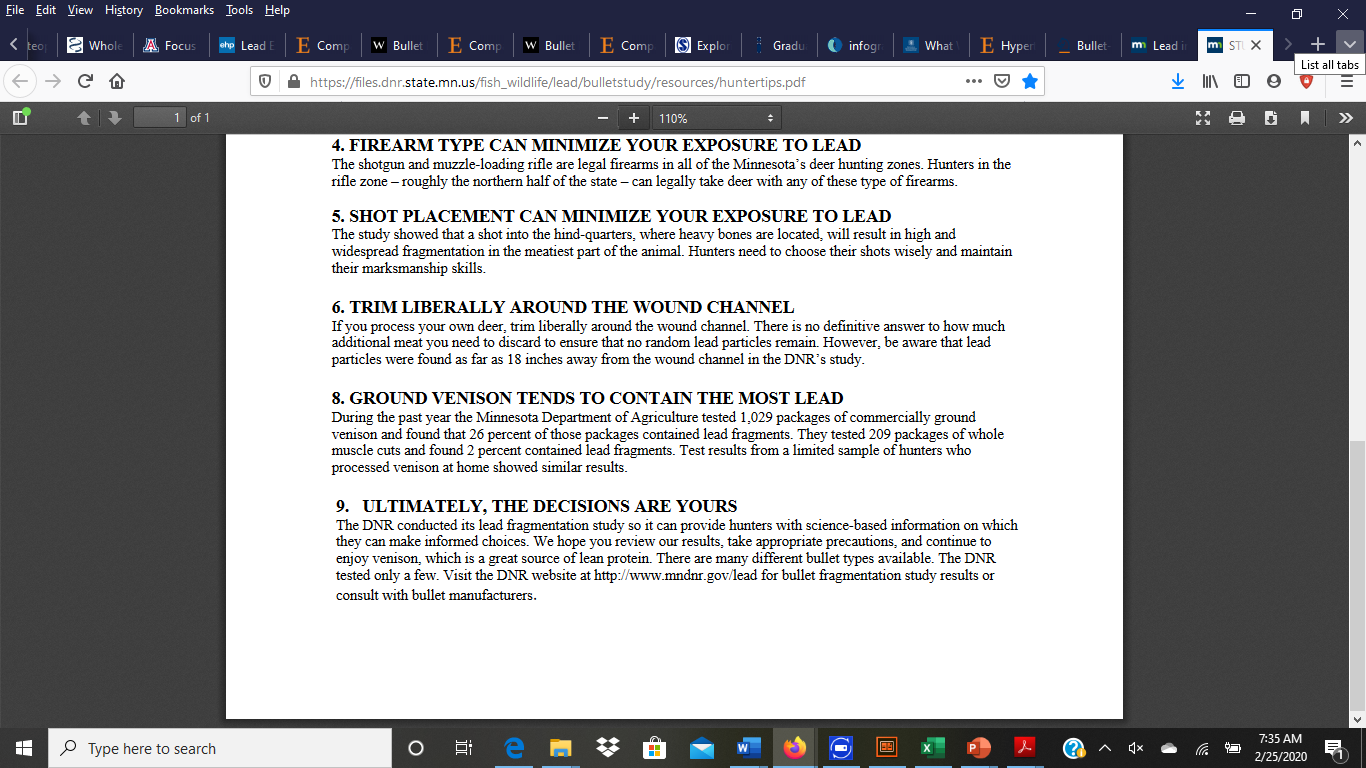
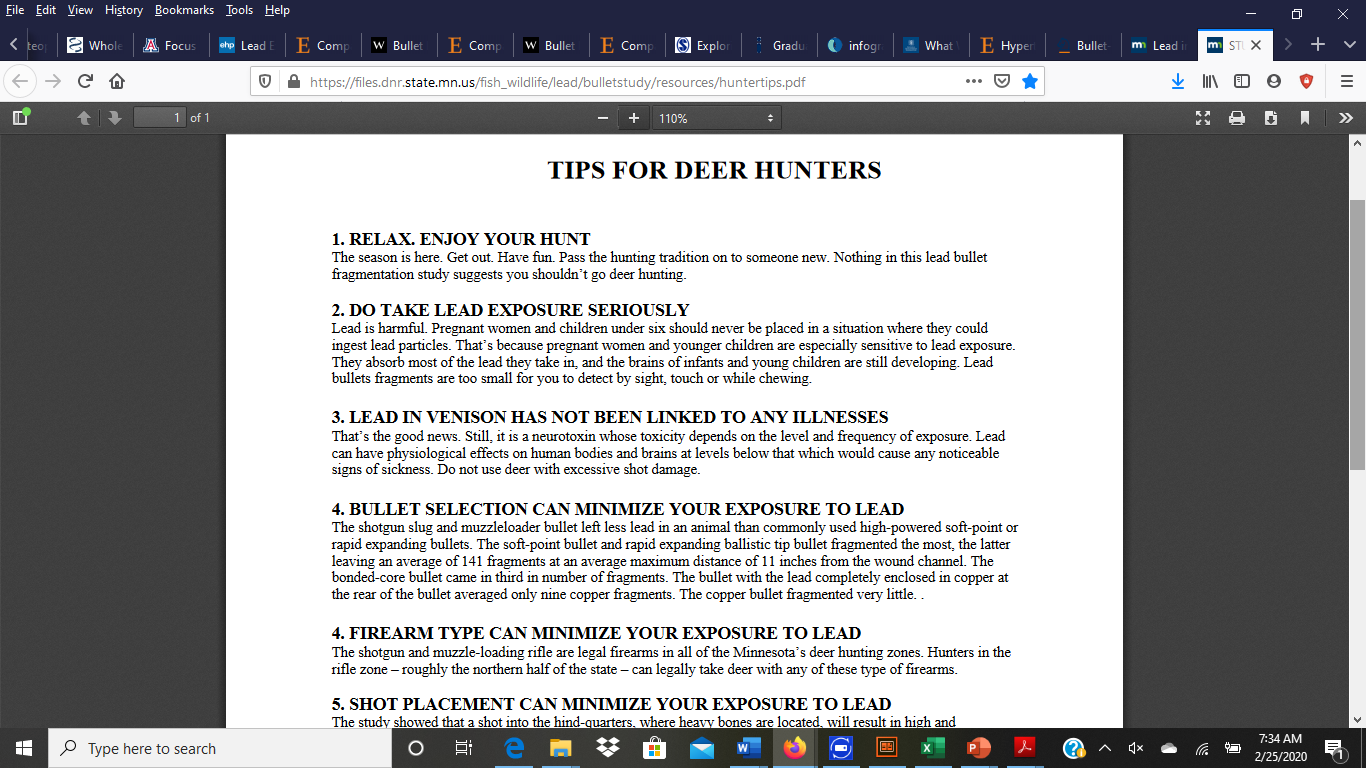
The most effective way to eliminate lead contamination is to use nonlead ammunition. For hunters who do use lead ammunition, choices that may minimize lead contamination include the following, according to the Minnesota Department of Natural Resources:

* Lead contamination may be reduced by:
  + Executing good shot placement (avoiding regions of the animal’s body with heavy bones, such as hips or shoulders).
  + Hunting with shotguns or muzzleloaders instead of high-powered rifles.
  + Avoiding soft-point lead bullets and rapid expanding ballistic tip rifle bullets.
  + Avoiding rinsing the carcass.
* The likelihood of consuming lead from a contaminated carcass may be reduced by:
  + Trimming away several inches from the wound channel.
  + Avoiding grinding damaged meat and avoiding eating ground meat.
  + Avoiding using acidic cooking ingredients such as vinegar or wine with lead-shot meat.

# Conclusions

There is no safe threshold for lead exposure, and scientific evidence suggests that consumption of lead-hunted meat is a risk factor for exposure to lead. However, the topic of lead-hunted meat is currently under the radar in the field of public health. Venison donation programs across the country do not inspect hunted meat for lead, an oversight that should be addressed. In addition, the topic of lead-hunted meat should be included in preventative information about lead exposure as well as questionnaires used to identify patients at high risk of lead exposure, which frequently omit this topic. Preventative information should also be made more accessible to the hunting community, including through pediatricians and obstetricians. This information should take into consideration what people in the hunting community will find to be most useful, and whom they trust to communicate that information. Specific information should be provided about potential health effects of long-term, low-level exposure to adults, including women’s reproductive health.

Appendix: Tip Sheet for Deer Hunters Developed by the Minnesota Department of Natural Resources



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