Discover Food

Brief Communication

X-ray screening of donated wild game is insufficient to protect children from lead exposure

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Abstract
Worldwide hunters distribute game meat as a gesture of community bonding and as an essential nutritional resource for those facing food insecurity, especially among children and adolescents. Nonetheless, the risk of lead (Pb) contamination from lead-based bullets is not widely acknowledged. Although medical radiography (X-ray) is the standard method to detect lead in meat donations, its efficacy in conclusively identifying lead contamination in game meat samples remains unknown. To address this deficiency, hunters-provided game meat samples were analyzed using both X-ray and inductively-coupled plasma mass spectrometry (ICP-MS). By ICP-MS, 48% of these samples contained lead levels exceeding the daily intake benchmarks for children, including the samples in which no lead was identified by X-ray screening. This finding means that food insecure individuals need to make an unenviable decision between risking lead exposure in donated meat or forgoing a potentially critical food source.

Keywords Firearm · Heavy metal · Hunting · Food security

Abbreviations

ICP-MS	Inductively-coupled plasma mass spectrometry
ILAC-MRA	International Laboratory Accreditation Cooperations, Mutual Recognition Arrangement
IRL	Interim reference level
FDA	Food and drug administration
Pb	Lead

1 Introduction

Worldwide, a time-honored tradition among hunters is the sharing of game meat from either trophy or meat hunting with their community, a practice fostering camaraderie and aiding those in need. In the United States, for example, this sharing can be informal (friends and family) or formal with over 40 states operating game meat donation programs associated with food banks, facilitating the distribution of roughly 1 million kilograms of game meat annually [1]. In many other world areas, food banks are local community run organizations that have similar types of distribution schemes, sometimes

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including wild game meat harvested by hunters and cullers. For many food-insecure individuals, particularly children and adolescents, this shared meat becomes an invaluable source of iron, and an important part of their nutritional intake. However, an often-overlooked aspect of this practice is the potential for lead contamination in game meat due to the use of lead bullets. As many hunters are unaware of these associated risks, regardless of the hunting context, the recipients of donated meat are less likely to be aware of the potential health risks of Pb contamination in donated meat.

The most common hunting bullet is a lead core with a copper jacket (Fig. 1A) and when an animal is shot, millions of sub-microscopic bullet fragments are dispersed throughout the carcass (Fig. 1B) [2]. This fragmentation occurs regardless of where the animal is shot, and there is more fragmentation if the bullet strikes hard material such as bone. When donated game meat is screened for lead contamination, it is done by medical radiography X-ray to screen for any metal contamination [3]. Using X-ray, 7–15% of submitted meat donations are radiologically positive for metal [4], meaning they had metal contamination. The fragments are most likely to be lead [5, 6]. Leontowich et al. [7] proved that it is impossible to determine the elemental composition of metal fragments in a medical X-ray image of gelatin, meat, or any other material, and questioned the effectiveness of X-ray imaging methods used to screen wild game donations at food

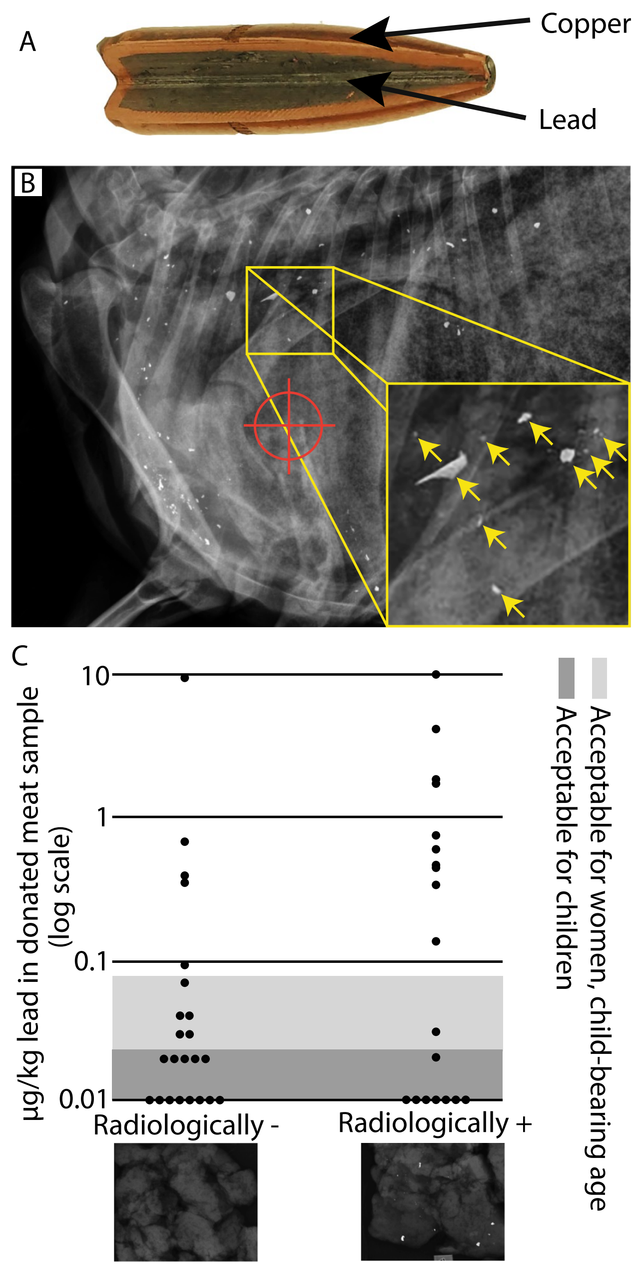

Fig. 1 X-ray is insufficient to identify wild game meat contaminated with lead. **A** Common bullet construction is lead core with a copper jacket. Lead is the central part of the bullet with a copper jacket primarily incorporated in the design to reduce lead deposition in the barrel (commonly referred to as fouling) when the bullet is shot from the firearm. A vast majority of bullets used have this type of construction. **B** When a lead bullet impacts an animal, lead shrapnel (a majority of which is too small to see on an x-ray) is dispersed throughout the carcass. This x-ray image shows metal fragments throughout a feral goat shot with a copper-jacketed lead 30 calibre rifle bullet. The bullseye identifies the bullet impact point. **C** Based on a standard serving size, the FDA Interim Reference Levels for lead were used to establish acceptable thresholds for lead contamination in donated meat for children and women of child-bearing age. Any samples above these thresholds exceed the daily allowable amount of lead. It is not possible to determine if metal fragments detected by X-ray are lead, copper, or another metal contaminant. These images are from samples of mince provided by hunters

banks for lead bullet fragments. Thus, it is unknown if existing radiologic screening programs are sufficient to identify and reduce or eliminate lead exposure.

2 Methods and materials

Between 25 April 2022 and 25 August 2022 we collected game meat samples from 44 animals from 38 hunters across New Zealand. Hunters were recruited to contribute samples through an article in a hunting magazine as well as radio coverage and newspaper articles. We asked hunters to submit mince (ground) meat samples from their stores that they had harvested. These samples could have been processed by the hunter or through a professional processing service. These collections were carried out in accordance with relevant guidelines and regulations and all experimental protocols were approved by the Nelson Marlborough Institute of Technology. Minced meat is most likely to be harvested from the forequarter, the area corresponding to the ideal shot placement to kill the animal (chest cavity) and therefore most likely to be contaminated. As hunters provided samples they had self-harvested and processed, these samples demonstrate real-world evidence regarding lead contamination in harvested game.

Samples were screened by X-ray (Electomed SHIMADZU, R-20C) and reviewed for metal fragments by a musculoskeletal radiologist (Garret M Powell); and subsequently analysed by ICP-MS to quantify lead levels (Cawthron Institute, Nelson, NZ; ILAC-MRA accredited; method APHA 3125B; detection limit of 0.01 mg/kg). The ability of metal fragments to be detected was limited by the X-ray and not the radiologist. Children ≥ 6 years old typically consume a standard meat serving size of 100 g [8]. The US FDA has set the Interim Reference Level (IRL) for lead exposure as 2.2 µg/day for children and 8.8 µg/day for females of childbearing age, meaning that any meat product with a lead concentration ≥ 0.022 mg/kg for children, or ≥ 0.088 mg/kg for females of childbearing age, would exceed the IRL with one meal [9]. A Fischer's exact test was used to determine if radiologically-positive samples predicted samples with lead levels that exceeded the acceptable level threshold for these two groups.

3 Results

Measured by ICP-MS, 48% (21/44) of the samples exceeded the acceptable daily lead intake for children and 27% (12/44) exceeded the acceptable daily lead intake for females of childbearing age. When comparing the radiologically-positive samples and those exceeding the safe level of lead in meat there was not a relationship for the children's threshold ($P = 0.54$), but there was a relationship for the women of childbearing age threshold ($P = 0.03$; Fig. 1C). Thus, medical radiography X-ray screening of wild game meat does not allow meat products with unacceptable lead levels for children to be identified.

4 Discussion

There is a known risk of lead exposure in eating wild game meat [10], but individuals receiving game meat from hunters may not be aware of this risk. Our data suggest that the most widely applied method within this field of research of X-ray screening technique for food banks, when used, is insufficient to identify all wild game meat products with concentrations of lead that are unacceptable for children–thus providing donation recipients inaccurate information regarding the risk of lead exposure. This deficiency is likely due to the presence of lead fragments that are too small to be seen by X-ray [7]. Additionally, samples that were radiologically positive for metal fragments, but did not contain lead by ICP-MS, would have been identified as lead contaminated when no measurable lead was detected. Non-lead ammunition is available, but an overwhelming majority of hunters use lead-based ammunition [6]. Hunters use lead-based ammunition because of historical precedence, cost and availability. Hunters have a right to choose the ammunition they use in hunting and similarly they can choose to feed the meat harvested with lead bullets to their families. Individuals receiving donated meat, however, are unlikely to be aware of the risks of lead exposure in the wild game meat regardless of shot placement. Future research should focus on: 1. Determining if this lead-contaminated meat results in elevated blood lead levels; 2. Techniques to identify meat products contaminated with lead; and, 3. Outreach to hunters describing the potential risks of using lead ammunition. We are unaware of any programs that warn consumers of the potential for lead exposure through game meat.

As current screening methods are insufficient, and there are no other established screening alternatives to protect children from meat contaminated with lead bullet fragments, this situation creates a conundrum: should individuals receiving donated products risk malnutrition forgoing free meat or should they risk lead exposure? Requiring hunters to use lead-free ammunition when donating meat is a straightforward way to avoid requiring the beneficiaries to make an unnecessary and difficult decision. Unfortunately, previous experience with the voluntary removal of lead ammunition in hunting does not warrant optimism for this approach [11].

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Author contributions Profs Eric Buenz and Gareth Parry conceptualized and designed the study, secured funding, drafted the initial manuscript, and critically reviewed and revised the manuscript. Mr Simon Hunter and Dominik Berghamer collected data and critically reviewed and revised the manuscript. Dr Garret Powell collected data, performed the radiology analysis, and critically reviewed and revised the manuscript. Drs Ellen Cieraad and Jordan O Hampton designed the study protocol, secured funding, and critically reviewed and revised the manuscript. Profs Jon M Arnemo and Brent A Bauer provided study guidance, critically reviewed and revised the manuscript for important intellectual content. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Data availability Anonymized data available upon request.

Declarations

Competing interests The authors have no competing interests to disclose.

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