Associations between consumption of large game animals and blood lead levels in humans in Europe: the Norwegian experience

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ABSTRACT

Lead toxicity was re-assessed by international risk assessment bodies in 2010 and 2011 and was seen as more toxic than in previous risk assessments. No tolerable intakes of lead have been identified. High lead levels in minced meat from moose *Alces alces* hunted using expanding lead-based ammunition has previously been reported in Norway. In 2012, the Norwegian Scientific Committee for Food Safety (VKM) assessed the risk of lead exposure from cervid meat to the Norwegian population. In conjunction with that, the Norwegian Institute of Public Health investigated associations between cervid meat consumption and concentrations of lead in blood in Norwegians (the Norwegian Game and Lead study). The results showed that cervid game meat consumption once a month or more was associated with approximately 31% increase in blood lead concentrations. The increase seemed to be mostly associated with consumption of minced cervid meat. VKM concluded that the blood lead concentrations measured in participants in the Norwegian population studies were in the range of, and partly exceeding, the reference values for increased risk of high blood pressure and increased prevalence of chronic kidney disease in adults, and for neurodevelopmental effects in children. The additional lead exposure from cervid meat in frequent (monthly or more often) consumers of such meat is therefore of concern. For these reasons, continued efforts are needed to reduce lead exposure in the population.

Key words: *human health, blood lead, cervid meat, risk assessment, dietary study, Norway*

INTRODUCTION

Lead is a naturally occurring heavy metal found in small amounts in the earth's crust and is additionally an environmental contaminant due to human activities. Humans and animals are exposed to lead through food, drinking water, air and dust. This exposure and its subsequent accumulation in the body is known to be harmful both to humans and animals.

In 2010 and 2011, respectively, both the European Food Safety Authority (EFSA) and the Joint Food and Agriculture Organisation/World Health Organisation Expert Committee on Food Additives (EFSA 2010, JECFA 2011) concluded, based on dose-response analyses, that there were no obvious thresholds for critical endpoints of lead exposure, *i.e.* there is not a level under which there is no increased risk of adverse health effects. Neurodevelopmental effects in children and increased blood pressure in adults are critical effects of lead exposure identified by both EFSA and JECFA (EFSA 2010, JECFA 2011). Children are more sensitive than adults to the effects of lead because their brain is under development. Increased blood pressure due to lead exposure is not an adverse outcome by itself, but is associated with increased risk of cardiovascular mortality. The EFSA Panel on Contaminants in the Food Chain (CONTAM) (EFSA 2010) identified Benchmark Dose Lower-confidence Limits (BMDL) for reduction in IQ, increased blood pressure and prevalence of chronic kidney disease (Table 1).

Table 1: **Overview of reference values for blood lead concentrations** (from VKM 2013, based on EFSA 2010)

Blood lead concentration (µg/l)	Explanation
$BMDL_{01}$: 12	1% reduction in full scale IQ in children (= 1 point reduction in IQ)
$BMDL_{01}$: 36	1% increase in systolic blood pressure in adults (1.2 mmHg given a blood pressure of 120 mmHg)
$BMDL_{10}$: 15	10% increased prevalence of chronic kidney disease in adults

Throughout Europe lead is commonly used in rifle ammunition for cervid hunting. The use of lead shot for smaller animals including wild birds was prohibited in Norway in 2005. However, on February 3rd 2015, the Norwegian parliament voted to permit the use of lead shot for hunting outside wetlands and outside shooting ranges. This political decision was made against recommendations from the environmental and health advisory bodies in Norway. Norwegian researchers have reported findings of high lead levels (mean 5.6 mg/kg, max 110 mg/kg) in minced meat from moose *Alces alces* hunted using expanding lead-based ammunition (Lindboe *et al.* 2012). Maximum levels of lead (0.1 mg/kg) have been set by the European Commission (under Commission Regulation 1881/2006 [EC 1881/2006]) for meat from livestock animals, but no maximum levels have been set for game meat. In 2012, the Norwegian Food Safety Authority requested the Norwegian Scientific Committee for Food Safety (VKM) to assess the risk of lead exposure from cervid meat to the Norwegian population. Further, VKM was asked to describe the distribution of lead from ammunition in the carcass and to estimate the tissue area associated with the wound channel that has to be removed in order to reduce the risk. VKM was also asked to present, if any, other appropriate measures, in addition to removing tissue, in order to limit the content of lead residues from ammunition in cervid meat. Finally, VKM was asked to assess the significance of lead exposure to the health of dogs if they were fed with trimmings from the wound channel. The risk assessment was published in June 2013 (VKM 2013). The results of the human health risk assessment and the conclusions regarding possible measures to reduce exposure are presented here.

To improve the scientific basis for the VKM risk assessment the Norwegian Institute of Public Health initiated The Norwegian Game and Lead study. The aim of the study was to investigate associations between cervid meat consumption and concentrations of lead in blood in Norwegians. The outcome from this study was published in 2013 (Meltzer *et al.* 2013) and was used in the VKM risk assessment. In addition, associations between cervid meat consumption and blood lead concentrations in other available studies from Norway were explored by the Norwegian Institute of Public Health.

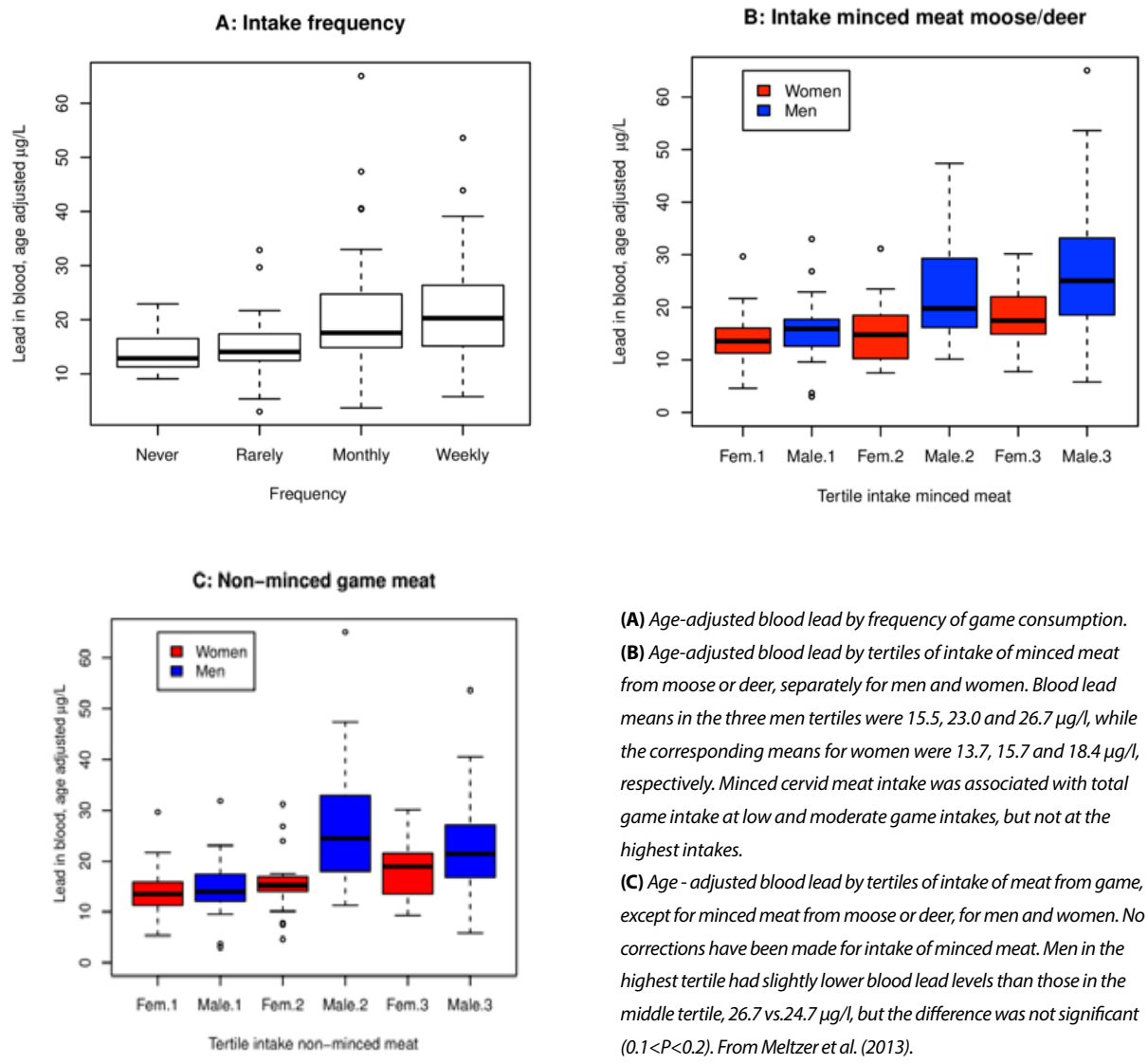
METHOD

FOR THE NORWEGIAN GAME AND LEAD STUDY

The Norwegian Game and Lead study (Meltzer *et al.* 2013) was conducted in 2012 in adults (n = 147) with a wide range of cervid game meat consumption. The main aim was to assess whether high consumption of lead-shot cervid meat is associated with increased concentration of lead in blood. A second aim was to investigate to what extent factors apart from game meat consumption explain observed variability in blood lead levels. Participants were asked about the frequency of cervid game meat consumption (never, rarely during a year, one to three times per month and one or several times per week) and data were collected on their background (age, height, occupation, residence), hunting habits (number of years hunting, assembling own ammunition, number of shots fired, type of hunting, *etc.*), on modifying factors (dietary supplements, alcohol consumption, smoking, *etc.*) and consumption of game (moose, red deer *Cervus elaphus*, roe deer *Capreolus capreolus*, reindeer *Rangifer tarandus*, and small game). Detailed information on game consumption included whether the game was whole meat, minced meat or offal, whether the meat was from their own hunting or purchased, and consumption within both the last month and the last year.

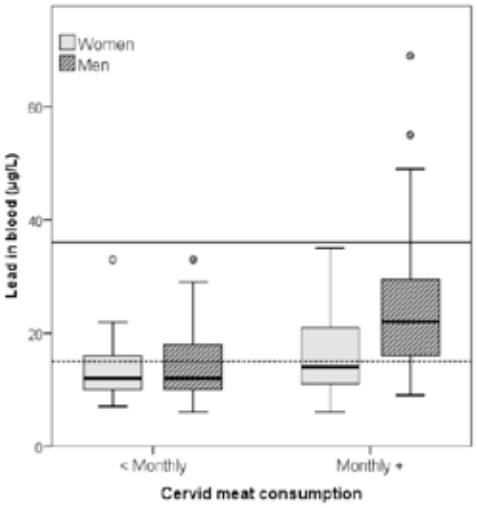
RESULTS

Median (5 and 95 percentile) blood lead concentration in the participants was 16.6 µg/l (7.5 and 39 µg/l). An optimal multivariate linear regression model for log-transformed blood lead indicated that cervid game meat consumption once a month or more was associated with approximately 31% increase in blood lead concentrations. The increase seemed to be mostly associated with consumption of minced cervid meat, particularly purchased minced meat (Figure 1). However, many participants with high game meat intake over a long period of time had low blood lead concentrations. Cervid meat together with the number of bullets shot per year, years of game consumption, self-assembly of bullets, wine consumption and smoking jointly accounted for approximately 25% of the variation in blood lead concentrations, while age and sex accounted for 27% of the variance. Blood lead concentrations increased approximately 18% per decade of age, and men had on average 30% higher blood lead concentrations than women. Hunters who assembled their own ammunition had 52% higher blood lead concentrations than persons not making ammunition. In conjunction with minced cervid meat, wine intake was significantly associated with increased blood lead. The proportion of participants with blood lead levels exceeding the EFSA BMDLs (Table 1) is illustrated in Figure 2.



(A) *Age-adjusted blood lead by frequency of game consumption.*
(B) *Age-adjusted blood lead by tertiles of intake of minced meat from moose or deer, separately for men and women. Blood lead means in the three men tertiles were 15.5, 23.0 and 26.7 µg/l, while the corresponding means for women were 13.7, 15.7 and 18.4 µg/l, respectively. Minced cervid meat intake was associated with total game intake at low and moderate game intakes, but not at the highest intakes.*
(C) *Age - adjusted blood lead by tertiles of intake of meat from game, except for minced meat from moose or deer, for men and women. No corrections have been made for intake of minced meat. Men in the highest tertile had slightly lower blood lead levels than those in the middle tertile, 26.7 vs.24.7 µg/l, but the difference was not significant (0.1<P<0.2). From Meltzer et al. (2013).*

Figure 1: **Age-adjusted blood lead by frequency of consumption**



Box plot details: the horizontal lines indicate the median blood lead concentration; the box indicates the interquartile range (IQR); the vertical bars represent observations within 1.5-times the IQR; and the circles indicate observations more than 1.5 times the IQR away from the box, considered outliers. The dashed horizontal line indicates the BMDL10 of 15µg/l for increased prevalence of chronic kidney disease and the solid horizontal line indicates the BMDL01 for increased systolic blood pressure. From VKM (2013), adapted from results in Meltzer et al. (2013).

Figure 2: **Proportion of participants with blood lead above BMDLs**

DISCUSSION

The results indicate that hunting practices such as use of lead-based ammunition, self-assembly of lead-containing bullets and use of lead-contaminated meat for mincing to a large extent determine human exposure to lead from cervid game consumption.

Lead exposure from cervid meat can be seen as additional to exposure from other foods, of which the main food groups contributing in the general population are grains and grain products, milk and other dairy products, non-alcoholic beverages and vegetables (EFSA 2012). According to the most recent (2012) representative national dietary survey in Norway, mean game (including cervid) meat consumption was low, at approximately 5-7 meals per year (VKM 2013). However, in several surveys in Norway, a large proportion (40 to 70%) of the participants consumed cervid meat at least once a month or more often (Birgisdottir *et al.* 2013, VKM 2013).

The mean or median concentrations of lead in blood in various Norwegian studies varied from 11 to 27 µg/l, which is in the same range as studies in most European countries from the last 10 years (Birgisdottir *et al.* 2013, VKM 2013). Blood lead concentrations were lower in pregnant women than in other adult population groups in Norway (VKM 2013). No information on blood lead levels in Norwegian children is available (VKM 2013). Recent data show that the geometric mean lead level in children of Swedish hunters was 11.7 µg/l (Forsell *et al.* 2014).

Associations between game meat consumption and blood lead concentration have been investigated in four population studies in Norway that were conducted prior to the Norwegian Game and Lead study (Birgisdottir *et al.* 2013, VKM 2013). In the three studies performed in the years 2003-2005, a significant association between game meat consumption and higher blood lead concentration was only seen in the subgroup of male participants in one of the studies (the Norwegian Fish and Game study). Furthermore, associations have been observed in two recent Swedish studies (Bjermo *et al.* 2013, Forsell *et al.* 2014) and a study from North Dakota, USA (Iqbal *et al.* 2009). None of the Norwegian studies could fully investigate the potential association between small game consumption and blood lead levels, because of infrequent consumption of small game among the participants. However, such associations have been observed in two studies in Greenland (Bjerregaard *et al.* 2004, Johansen *et al.* 2006). It is notable that lead concentrations in small game species, such as gamebirds, tend to be higher than in larger game, like deer (Pain *et al.* 2010) and therefore the relationship between blood lead and game consumption is logically likely to be present in frequent consumers of small game as well. Results from studies on associations between game meat consumption and blood lead concentration are summarised in Table 2.

Table 2: **Studies of association between game consumption and lead in blood**

Study, country	Sampling year (n)	Association between blood lead and frequency of game consumption?	Reference
Greenland	1993-1994 (162 adult men and women)	Yes	Bjerregaard *et al.* 2004
Greenland	2003-2004 (50 adult men)	Yes	Johansen *et al.* 2006
Fish and Game study, Norway	2003-2004 (184 adults)	Yes, but only in men	Birgisdottir *et al.* 2013
MoBa validation study, Norway	2003-2004 (119 pregnant women)	No	VKM 2013
Lake Mjøsa study, Norway	2004-2005 (64 adults)	No	VKM 2013
North Dakota, USA	2008 (736 adults and children)	Yes	Iqbal *et al.* 2009
Riksmaten, Sweden	2010-2011 (273 adults)	Yes	Bjermo *et al.* 2013
Lead and Game study, Norway	2012 (147 adults)	Yes	Meltzer *et al.* 2013
Swedish hunters and families	2013 (113 adults)	Yes	Forsell *et al.* 2014 (report in Swedish)

The distribution of fragmented lead ammunition within game meat is dependent on several variables. Available studies on lead concentrations in meat at different distances from the wound channel were summarised in the VKM report from 2013. Based on these data, it was concluded that removal of meat around the wound channel reduces lead exposure from cervid meat consumption. One study indicated that lead concentrations above 0.1 mg/kg can be found at a distance of 25 cm from the wound channel in red deer and wild boar *Sus scrofa* shot with various unknown ammunition (Dobrowolska and Melosik 2008). However, there were no available studies in moose, and the data did not allow a firm conclusion on the amount of meat needed to be trimmed around the wound channel in order to remove lead originating from the ammunition. Other possible measures identified by VKM to reduce lead exposure from cervid meat would be to use lead based ammunition with low fragmentation or ammunition without lead.

CONCLUSIONS AND RECOMMENDATIONS

Based on the data available in 2013, VKM concluded that the blood lead concentrations measured in participants in the Norwegian population studies were in the range of, and partly exceeding, the reference values for increased risk of high blood pressure and increased prevalence of chronic kidney disease in adults, and for neurodevelopmental effects in children.

The additional lead exposure from cervid meat in frequent (monthly or more often) consumers of such meat is therefore of concern. For these reasons, continued efforts are needed to reduce lead exposure in the population.

Based on the risk assessment from VKM, the Norwegian Food Safety Authority recommends that:

- Children, pregnant women, women of reproductive age and people with high blood pressure should not eat lead-shot cervid meat more often than once a month.
- The use of non-lead bullets removes the risk of lead contamination of game meat.
- If lead ammunition is used, one should use bullets that only fragment to a small extent on impact.
- Meat removal in a radius of 30 cm (*i.e.* a 60 cm diameter) along the bullet channel is necessary. The effect of this is however not fully known.

These recommendations are in line with those produced by food safety and risk assessment agencies of several other European countries in recent years (Table 3).

Table 3: **Advice by national food safety and risk assessment agencies regarding the consumption of game meat shot using lead ammunition**

Institute	Date	Advice
Federal Institute for Risk Assessment, Germany (BfR 2011)	September 2011	BfR recommends that children, pregnant women, and women planning to have children should not eat meat from game animals killed by hunters. The consumption of game meat contaminated by lead bullets should definitely be avoided. Cutting out large sections of meat around the bullet hole is not always enough to guarantee removal of lead.
Scientific Committee of the Spanish Agency for Food Safety and Nutrition Safety (AESAN 2012)	February 2012	AESAN recommends that children under 6 years of age, pregnant women and women who plan on getting pregnant should avoid eating the meat of game that has been shot with lead ammunition. This is because the lead fragments cannot be removed from the meat completely. Wherever possible, limiting the use of lead ammunition in favour of other available alternatives should be promoted.
National Food Agency, Sweden (SNFA 2014)	June 2012 June 2014	Pregnant women and children 0-7 yrs. should avoid eating meat shot with lead ammunition. Using lead-free ammunition eliminates the problem of elevated lead levels in game meat and products made from game meat. Meat from the bullet channel and the affected meat next to the bullet channel and another 10 cm seemingly unaffected meat should not be used for food, but discarded.
Food Standards Agency, UK (FSA 2012)	October 2012	The Food Standards Agency is advising people that eating lead-shot game on a frequent basis can expose them to potentially harmful levels of lead. The FSA's advice is that frequent consumers of lead-shot game should eat less of this type of meat. This advice is especially important for vulnerable groups such as toddlers and children, pregnant women and women trying for a baby, as exposure to lead can harm the developing brain and nervous system.
The Norwegian Food Safety Authority (VKM 2013)	October 2013	Children, pregnant women, women in fertile age and people with high blood pressure should not eat lead-shot cervid meat more often than once a month. The use of non-lead bullets removes the risk of lead contamination of game meat. If lead ammunition is used, one should use bullets that fragment to a small extent upon impact. Meat removal in a radius of 30 cm along the bullet channel is necessary. The effect of this is however not fully known.

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X-ray of a roe deer *Capreolus capreolus* shot with a conventional lead-based (semi-jacketed) bullet: note the extent of fragmentation of the lead projectile and distance from the wound canal to which the consumer is then exposed.

Photo Credit: Oliver Krone/Leibniz Institute for Zoo and Wildlife Research, Berlin