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Subject: Epi-AID Trip Report: Assessment of human health risk from consumption of wild game meat with possible lead contamination among the residents of the State of North Dakota.

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Introduction

Large game hunting plays a significant role in the state economy of North Dakota and is a popular tourist attraction. During hunting season and throughout the year, a substantial proportion of families in ND consume wild game, especially venison. A large proportion of venison (around 17,000 lbs every year) is also donated to local food pantries and serves as an important source of protein for low income families.

Recently, a local physician notified the North Dakota Department of Health (NDDoH) that in 53 of 95 packets of ground venison donated to several food pantries, x-ray analysis revealed evidence of metal fragments. Further analysis identified these fragments as lead, and found the levels were much higher than expected. The bullets used to kill wild game are the most likely source of this lead. The discovery of lead fragments prompted a recommendation from the NDDOH to stop distributing the remaining donated venison. NDDoH also released a public notification to advise people of the unknown risk of lead exposure associated with the consumption of large animals killed by lead bullets. NDDoH then requested assistance from CDC to investigate the human health risk associated with consumption of wild game, with an emphasis on venison, and to assist in the development of scientifically sound recommendations for the safe processing and consumption of wild game killed by lead bullets. The findings of this investigation also have great impact on the surrounding states as large game hunting and the consumption of wild game is highly prevalent in this region of the country.

On May 13, 2008, a CDC team consisting of Epidemic Intelligence Service Officers (EISO) Shahed Iqbal, PhD, MBBS, Kelly Loring, ND, MPH and epidemiologist Wendy Blumenthal, MPH deployed in North Dakota to conduct a study on lead exposure from wild game consumption. Drs. Chinaro Kennedy, DrPH, MPH, and Fuyuen Yip, PhD, MPH supervised the study.

Objectives

1. To determine whether an increase in blood lead levels (PbB) is associated with consumption of wild game.
2. To identify population subgroups by age, race, sex, and other socio-demographic characteristics who might be at risk of having increased lead levels due to wild game consumption.

Methods

A retrospective cohort study was conducted to determine the association between consumption of wild game and PbB. Exposure to wild game was defined based on self-reported consumption or on levels of consumption of wild game meat that included venison, other wild game (e.g., elk, moose), and birds (excluding water fowl). Participants were eligible for inclusion if they were

- a) ≥ 2 years of age,
- b) residents of North Dakota,
- c) had sufficient knowledge and understanding of the English language for participation, and
- d) agreed to provide blood samples.

Following an NDDoH press release announcing the study, participants were recruited through a convenience sampling approach at local public health clinics in six different cities, namely, Bismarck, Fargo, Grand Forks, Minot, Jamestown, and Dickinson (Figure 1).

Participants were also recruited from two additional sites in Bismarck. From 5/16/2008 to 5/30/2008, data were collected via face-to-face interview. Data collection took place over a 2-week period, but was not conducted simultaneously in all cities.

Before enrolling in to the study, all participants signed a consent form. For any children <18 years of age, parental consent and child assent were obtained. Data were then collected on demographic and housing characteristics (e.g., age of housing, duration of residence in the same household, renovation, visible peeling of paint), current and previous lead-related hobbies (e.g., hunting, lead soldering, car/boat repair) and occupations (e.g., welding, construction, working in lead smelter, refinery, or lead mines), other possible sources of lead exposure (e.g., use of herbal medicine or make up, residence near a lead smelter/mine, use of South/Central American pottery, living in or travelling to South/Central America), and consumption of wild game. Information on frequency, duration, meat processing methods, and average serving size by type of wild game was also collected. Trained phlebotomists, using aseptic precautions, collected venous blood samples from all participants.

Blood samples were shipped, refrigerated with pre-frozen ice packs, to the CDC National Center for Environmental Health, Division of Laboratory Sciences in Atlanta, GA. Blood lead was measured using whole blood and inductively coupled plasma mass spectrometry. The minimum detection level for blood lead was 0.25µg/dl. For persons with no detectable levels of blood lead (n = 5), a value calculated as the detection limit divided by the square root of 2 was assigned (National Center for Environmental Health 2001).

Statistical analysis

Frequencies and proportions were reported for all variables, including socio-demographic and housing characteristics, lead-related occupations and hobbies, and wild game consumption including type, frequency, and average serving size. Both mean and geometric mean lead levels and frequency for PbB \geq 5 µg/dl were reported. Generalized Estimating Equation (GEE) methods were used to determine unadjusted and adjusted associations between PbB and other

variables using SAS software (version 9.1, Copyright © SAS Institute, Inc., 2002-2003, Cary, NC). Separate GEE models were developed by types of wild game (i.e., venison, other game, birds) to determine the association between frequency, duration, average food serving size, and PbB. Only significant variables in unadjusted models were included in the multivariate model. Race and income, commonly reported predictors of elevated PbB, were included in the multivariate model regardless of their significance in the unadjusted models. Parameter estimates with 95% confidence intervals and significance levels were reported for all models. Multivariate models with two-way interactions with the exposure variable (e.g., consumption of wild game) were considered. Missing values were reported for all frequencies. Some variables were not reported due to unilateral response (e.g., use of herbal medicine, residence near a lead smelter/mine, use of South/Central American pottery, previous blood lead test), ambiguity (e.g., travel to South or Central America), or a high number of missing values (e.g., additional exposure questions for children <6 years of age and pregnant women).

Results

Study population

A total of 742 participants were recruited from the six different cities in North Dakota. Two persons were found to be residents of the neighboring state of Minnesota and were excluded from all analyses (N = 740). The distribution of participants, by location, is provided in Table 1. Capillary blood samples were collected from two children as their parents refused venous blood draw. The results of these tests were included in the analysis. Additionally, one child refused blood draw, and blood draw was incomplete for two children and one adult. Blood samples from 736 persons were therefore included in the final analysis.

Almost half of the participants (48.1%) were ≥ 55 years of age. Participation among males (54.5%) was higher than among females (Table 2). Participants were predominantly white (98.2%) and non-Hispanic (96.4%). The majority of the study participants (65.7%) had graduated from college or had higher education. For most participants (73.5%), annual household income was \geq \$40,000.

Approximately 31.0% of participants shared the same household with at least one other participant (Table 3). Most of the residences were built in or after 1950 (83.1%). More than half of the participants reported living in the same household for >10 years (53.5%) and had some renovation done on the home while they were living there (53.7%). Most participants did not observe any peeling paint inside or outside their homes (85.5%).

With respect to other potential lead exposures, approximately 13.0% of the study participants reported they were currently engaged in at least one lead-related occupation, while 36.5% reported a previous lead-related occupation (Table 4). Most of the participants (63.9%) reported currently having at least one lead-related hobby, and 55.9% reported previously having lead-related hobbies.

Wild game consumption

Approximately 80.8% (N = 598) of the participants reported consuming at least one type of wild game (i.e., venison, other game, birds), while 86.5% (N = 517) reported consuming more than one type (Table 5). Among those who consumed wild game, almost all reported consuming venison (98.8%), and 64.5% and 84.4% reported consuming other game and birds, respectively. Study participants indicated that they primarily hunted the wild game they consumed, or it was hunted by family members or by friends (98.8%). Most of these participants (81.9%) reported processing their own meat or had family members process the meat. Among them, 92.1%

reported cleaning the meat around the wound channel. The remainder of the participants reported having their meat processed by meat packers/lockers (31.6%) and local butchers (9.2%).

With respect to frequency of consumption, most participants consumed venison throughout the year (80.5%). Nearly half reported consuming other game (49.2%) or birds (52.0%) occasionally or only during the hunting season (Table 6). In a given month, 62.2% of participants reported consuming venison at least once a week; they also reported consuming other game (69.2%) and birds (77.2%) at a frequency of less than once a week. Within the past month preceding the survey, 82.6% of participants had consumed venison; by comparison, only 45.3% and 40.4% had consumed other game and birds, respectively. Most of the participants reported grinding their venison (57.9%) but did not grind other game meat (57.0%) or birds (96.6%). When asked about approximate serving size, participants predominantly reported consuming an average of ≥ 2 oz. of venison, of other game, and birds per serving. Most of the participants reported consuming all three types of wild game for >10 years.

Laboratory results

A total of 734 blood samples—excluding two locally tested capillary samples—were sent to the NCEH laboratory for PbB analysis. Among all participants, the geometric mean PbB was $1.17\mu\text{g}/\text{dl}$ (Table 7); 1.1% had PbB $\geq 5\mu\text{g}/\text{dl}$. None of the participants had PbB above the CDC recommended threshold of $\geq 10\mu\text{g}/\text{dl}$ —the level at which CDC recommends case management.

Generalized Estimating Equation (GEE) analysis

In unadjusted Generalized Estimating Equations (GEE) models, variables including age, sex, education, age of housing, amount of time in the household, renovation, current and previous lead related occupations, current lead related hobbies, family members with lead-related

occupations or hobbies, and consumption of wild game were significantly associated with PbB (Table 8). In a multivariate-adjusted GEE model, age, sex, age of housing, current lead-related hobbies, and wild game consumption were significantly associated with PbB.

Specifically, compared with other age categories, participants aged ≥ 65 years had the highest geometric mean PbB (Table 8). After adjusting for all other confounding effects, participants 2–5 years of age, 6–24 years of age, 25–44 years of age, and 45–65 years of age, respectively, had 0.84 $\mu\text{g}/\text{dl}$, 1.10 $\mu\text{g}/\text{dl}$, 1.10 $\mu\text{g}/\text{dl}$, 0.44 $\mu\text{g}/\text{dl}$ lower PbB than those ≥ 65 years of age (Table 8). Males had PbB that were 0.28 $\mu\text{g}/\text{dl}$ higher than female participants. Participants living in residences built between 1950 and 1977 or before 1950 had higher PbB (0.19 $\mu\text{g}/\text{dl}$ and 0.43 $\mu\text{g}/\text{dl}$, respectively) compared with participants living in residences built after 1977. Currently having lead-related hobbies were associated with higher PbB compared with those who did not report lead-related hobbies.

Participants who consumed wild game had 0.30 $\mu\text{g}/\text{dl}$ higher PbB in comparison with those who did not consume wild game (Table 8). The multivariate model did not improve significantly when all two-way interactions between wild game consumption and other variables were considered in the model (data not shown). Participants who did not consume wild game within a month before data collection had significantly lower PbB for all game types (Table 9). Among those who reported consuming other game, a 0.40 $\mu\text{g}/\text{dl}$ increase in PbB was associated with having an average serving size of ≥ 2 oz. compared with those who consumed a lesser amount.

Discussion

In this study, the consumption of wild game was significantly associated with an increase in PbB. This increase could not, however, be attributed to one single game type: a substantial

overlap occurred in the types of wild game the participants consumed. Also, no linear increase in PbB was observed with an increase in the number of wild game types consumed. Nevertheless, after adjusting for other factors, the associated increase in PbB was highest among participants who consumed all three game types (i.e., venison, other game, birds) (data not shown).

Recent consumption of wild game and amount consumed per serving were also significant factors associated with PbB. For all game types, participants who reported consuming wild game within a month prior to data collection had significantly higher PbB in comparison with those who did not consume wild game within a month of the study. This could be explained by the fact that blood lead is an indicator of more recent exposure and supports the finding of a positive association between wild game consumption and PbB; in adults, the excretory half life of lead is approximately 30 days (ATSDR 2007; Rabinowitz et al. 1976). Among participants who reported consuming other wild game, an increase in PbB was also, after adjusting for other factors, associated with a larger average serving size (≥ 2 oz.).

While this study suggests that consumption of wild game meat can adversely affect PbB, no participant had PbB higher than the CDC recommended threshold of $10\mu\text{g}/\text{dl}$ —the level at which CDC recommends case management; and the geometric mean PbB among this study population ($1.17\mu\text{g}/\text{dl}$) was lower than the overall population geometric mean PbB in the United States ($1.60\mu\text{g}/\text{dl}$) (CDC 2005). The clinical significance of low PbB in this sample population and the small quantitative increase of $0.30\mu\text{g}/\text{dl}$ in PbB associated with wild game consumption should be interpreted in the context of naturally occurring PbB. Despite the decline in PbB in recent decades, the mean PbB in the population is several orders of magnitude higher than the levels of preindustrial human societies ($0.016\mu\text{g}/\text{dl}$) and the natural background of PbB in humans (Flegal and Smith 1992; Bellinger 2004). Among adults, increased risk of myocardial and stroke mortality have been observed to be associated with $\text{PbB} \geq 2\mu\text{g}/\text{dl}$ (Menke et al. 2006).

Furthermore, studies have consistently reported adverse neurocognitive effects in children at PbB <10µg/dl (Canfield et al. 2003; Lanphear et al. 2005; Tellez-Rojo et al. 2006; Kordas et al. 2006). Due to increased absorption and an under-developed blood brain barrier, children <6 years of age are considered to be more susceptible to the adverse effects of lead exposures (ATSDR 2007).

Most lead in adults is stored in the bones, and the concentration of lead increases with age. In comparison with 8 mg in children <16 years of age, the body burden of lead is estimated at approximately 200 mg in adults 60–70 years of age (ATSDR 2007; Barry 1975). Lead released from bone storage can therefore contribute to PbB (ATSDR 2007; O’Flaherty et al. 1982). For all game types, participants aged ≥ 65 years frequently reported consuming wild game for more than a decade (data not shown). This long-term cumulative exposure may have resulted in the observed increase in PbB in this age group compared with younger age groups.

Age of housing, male sex, and current lead-related hobbies were other significant factors associated with an increase in PbB. Increased PbB was associated with increase in housing age, which is consistent with our knowledge of environmental exposure to lead (CDC 2005). Higher PbB in males can be explained by the fact that males were almost four times more likely to report consuming wild game compared with females (data not shown). Hunting (53.5%), target shooting (32.0%), home remodeling or painting (18.6%), and reloading (15.7%) were most commonly reported lead-related hobbies and may have substantially contributed to the observed association with PbB.

Limitations

Findings from this study have limited generalizability. The study cohort was predominantly white, educated, and had higher incomes, and did not include persons who

received donated wild game meat from food pantries or other charitable organizations. As high levels of lead were detected in the meat packs donated to local food pantries in North Dakota and the surrounding states (Smith 2008), this group may have greater exposure to lead-contaminated wild game meat.

This study also included a small number of children <6 years of age; however, all of them reported consuming wild game meat. And due to increased rate of lead absorption, children as a whole may potentially be more vulnerable to exposure to lead from wild game consumption. In any event, further research is needed to determine the magnitude of the risk associated with wild game consumption among children and among the population who receives donated meat.

Additionally, most of the data collected were self-reported and may therefore, have been subject to information bias due to misclassification. Although the direction of the bias could not be ascertained, it is unlikely that the findings of the study were qualitatively impacted.

Conclusion

Among those who consumed wild game, most reported hunting as their source. Most participants reported processing the meat themselves and also reported cleaning the meat around the wound channel. Despite these precautions and despite the fact that a wide range of potential confounders were controlled for in the analyses, participants who consumed wild game had higher PbB in comparison with those who did not consume wild game. Careful review of cleaning practices and monitoring of meat packing processes may mitigate the risk of increased PbB from consumption of wild game shot with lead bullets.

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Figure 1: North Dakota study locations

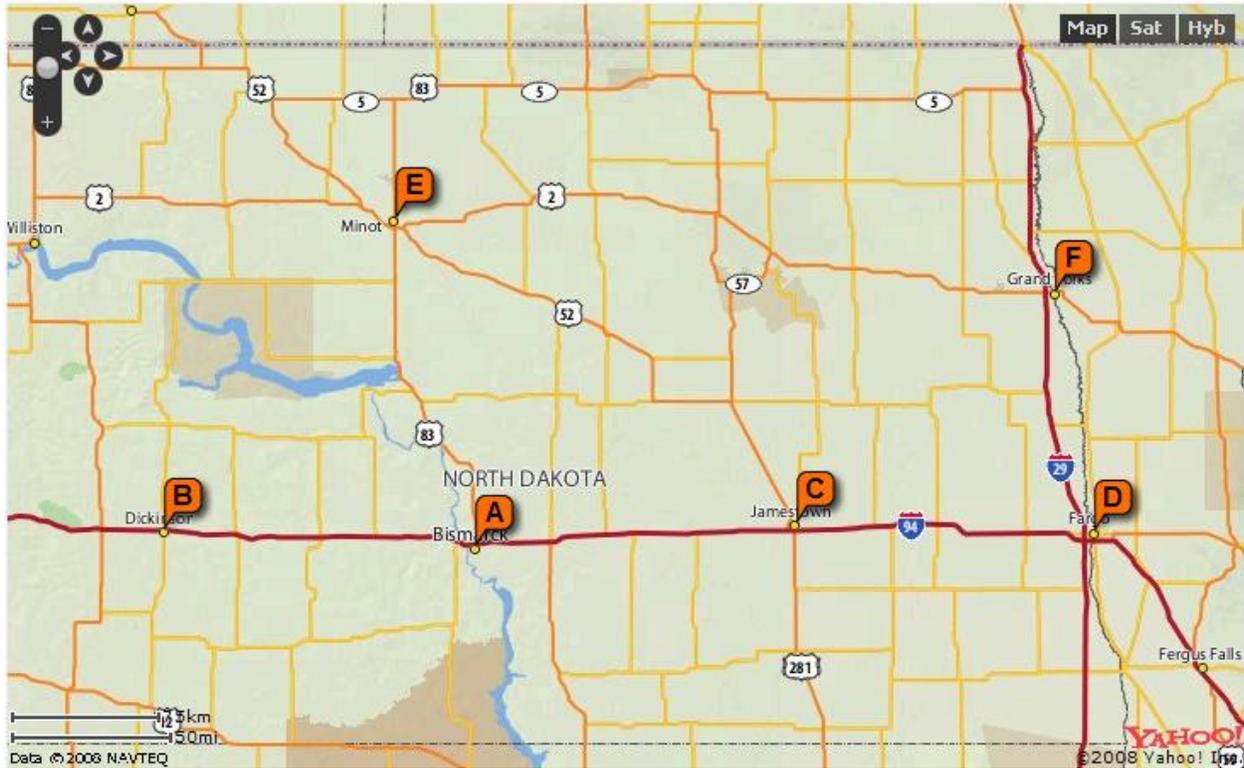


Table 1: Geographical distribution of recruitment of study participants (N=740)

Geographical unit	n(%)
Bismarck	229 (30.9)
Dickinson	70 (9.5)
Fargo	91 (12.3)
Grand Forks	96 (13.0)
Jamestown	126 (17.0)
Minot	128 (17.3)

Table 2: Demographic characteristics of the study participants (N=740)

Variables	n (%)
Age	
2 – 5 yrs	7 (0.9)
6 – 14 yrs	12 (1.6)
15 – 24 yrs	21 (2.8)
25 – 34 yrs	78 (10.5)
35 – 44 yrs	89 (12.0)
45 – 54 yrs	177 (23.9)
55 – 64 yrs	203 (27.4)
65 yrs or more	153 (20.7)
Sex	
Male	403 (54.5)
Female	337 (45.6)
Ethnicity	
Hispanic or Latino	7 (0.9)
Non-Hispanic or Latino	713 (96.4)
<i>Missing (n=19) or Refused (n=1)</i>	20 (2.7)
Race	
White	727 (98.2)
Other	12 (1.6)
Asian (n=4)	
Native Hawaiian/Pacific Islander (n=1)	
American Indian/Alaskan native (n=2)	
Other race (incl. multiracial) (n=5)	
<i>Refused</i>	1 (0.1)
Education	
Less than high school	12 (1.6)
High school graduate or equivalent	75 (10.1)
Some college	167 (22.6)
College grad or more	486 (65.7)
Income	
Less than \$15,000	10 (1.4)
\$15,000 - \$24,999	38 (5.1)
\$25,000 - \$39,999	104 (14.1)
\$40,000 or more	544 (73.5)
<i>Refused</i>	27 (3.6)
<i>Don't know</i>	6 (0.8)
<i>Missing</i>	11 (1.5)

Table 3: Housing characteristics of the study participants (N=740)

Variable	n(%)
Participants from same household	
One person	511 (69.0)
More than 1 person	229 (31.0)
House construction year	
1949 or before	119 (16.1)
1950 to 1977	297 (40.1)
1978 or after	318 (43.0)
<i>Don't know</i>	6 (0.8)
Living in the household	
2 months or less	7 (0.9)
3 months to a year	37 (5.0)
>=1 yr to 5 yrs	164 (22.2)
>=5 yrs to 10 yrs	135 (18.2)
>10 yrs	396 (53.5)
<i>Missing</i>	1 (0.1)
House Renovation/remodeling	
Currently undergoing renovation	42 (5.7)
Done within the last 12 months	76 (10.3)
Done beyond the last 12 months	279 (37.7)
No renovation done	338 (45.7)
<i>Don't know (n=4) or missing (n=1)</i>	5 (0.7)
Peeling paint or paint chips	
None	633 (85.5)
Yes	104 (14.1)
Inside	59 (8.0)
Outside	71 (9.6)
<i>Don't know (n=2) or missing (n=1)</i>	3 (0.4)

Table 4: Study participants' lead-related occupation¹ (N=717) and hobbies² (N=740)

	Currently n(%)	Previously n(%)
Lead-related occupations (any)	93 (13.0)	262 (36.5)
Lead-related occupations (more than one)	22 (3.1)	117 (16.3)
Lead-related hobbies (any)	473 (63.9)	414 (55.9)
Lead-related hobbies (more than one)	334 (45.1)	217 (29.3)
Household member ever having a lead-related occupation	166 (22.4)	
Household member ever having lead-related hobbies	411 (55.5)	

¹Auto repair, battery manufacture/repair, construction, home construction/painting, working in lead smelter/refinery/mine, plumbing or pipe fitting, radiator repair, welding, working in brass/copper foundry, gas station attendant, military/police officer, etc.

²Car/boat repair, casting (bullets, fishing weights, etc.), casting lead figures (toys, soldiers), furniture finishing, home remodeling/paint job, hunting, jewelry making, lead soldering, pottery/stained glass making, reloading, target shooting, welding, etc.

Table 5: Wild game consumption by type, source, processing, and cleaning methods

Variables	n (%)
Wild game consumption	598 (80.8)
Venison	591 (98.8)
Other wild game	386 (64.5)
Birds	505 (84.4)
Number of types of wild games consumed (N=598)	
One	81 (13.5)
Two	150 (25.1)
Three	367 (61.4)
Source of wild game	
Food pantries or similar	1 (0.2)
Hunting	591 (98.8)
Other sources	8 (1.3)
<i>Missing</i>	3 (0.5)
Meat processing	
Self/family members	490 (81.9)
Meat packers/processors/lockers	189 (31.6)
Butcher	55 (9.2)
<i>Don't know (n=7) or missing (n=4)</i>	11 (1.8)
Cleans wound channel (N=490)	
Yes	451 (92.1)
No	9 (1.8)
<i>Don't know (n=25) or missing (n=5)</i>	30 (6.1)

Table 6: Wild game consumption frequency, recent consumption, meat processing method, average serving size, and duration

Variable	Venison (N=591)	Other game (N=386)	Birds (N=505)
Consumption in a year			
Occasionally	101 (17.1)	163 (42.2)	180 (35.6)
Hunting season only	11 (1.9)	27 (7.0)	83 (16.4)
Year round	476 (80.5)	192 (49.7)	240 (47.5)
<i>Don't know or missing</i>	3 (0.5)	4 (1.0)	2 (0.4)
Consumption in a given month			
<1 time/wk	222 (37.6)	267 (69.2)	390 (77.2)
1-3 times/wk	278 (47.0)	84 (21.8)	90 (17.8)
>3 times/wk	90 (15.2)	30 (7.8)	20 (4.0)
<i>Don't know or missing</i>	1 (0.2)	5 (1.3)	5 (1.0)
Last time consumed wild game			
<1 month ago	488 (82.6)	175 (45.3)	204 (40.4)
1-6 months	68 (11.5)	104 (26.9)	191 (37.8)
>6 month ago	33 (5.6)	104 (26.9)	107 (21.2)
<i>Don't know or missing</i>	2 (0.3)	3 (0.8)	3 (0.6)
Meat processing method			
Ground	342 (57.9)	107 (27.7)	11 (2.2)
Not ground	91 (15.4)	220 (57.0)	488 (96.6)
Both	157 (26.6)	57 (14.8)	3 (0.6)
<i>Don't know or missing</i>	1 (0.2)	2 (0.6)	3 (0.6)
Portion size in average serving			
<2 oz	57 (9.6)	34 (8.8)	50 (9.9)
>= 2 oz	523 (88.5)	342 (88.6)	446 (88.3)
<i>Don't know or missing</i>	11 (1.9)	10 (2.6)	9 (1.8)
Duration of consumption (years)			
< 1 year	3 (0.5)	10 (2.6)	5 (1.0)
1-3 year	17 (2.9)	14 (3.6)	19 (3.8)
4-10 year	50 (8.5)	34 (8.8)	43 (8.5)
>10 year	514 (87.0)	321 (83.2)	431 (85.3)
<i>Don't know or missing</i>	7 (1.2)	7 (1.8)	7 (1.4)

Table 7: Description of blood lead results (N=736)

Descriptive statistics (µg/dl)	
Mean	1.46
Median	1.19
Standard deviation	1.09
Geometric mean	1.17
Minimum	0.18
Maximum	9.82
Frequency of $\geq 5\mu\text{g/dl}$	8 (1.1%)

Table 8: Geometric mean ($\mu\text{g}/\text{dl}$) and unadjusted and multivariate-adjusted associations between PbB and other variables in Generalized Estimating Equations (GEE) models (N = 736)

Variables	Geometric mean PbB ($\mu\text{g}/\text{dl}$)	Unadjusted Parameter estimates (95% CI)	Adjusted Parameter estimates (95% CI)
Age			
2 – 5 yrs	0.88	-1.021 (-1.251, -0.790) ^{††}	-0.843 (-1.122, -0.563) ^{††}
6 – 24 yrs	0.60	-1.234 (-1.532, -0.936) ^{††}	-1.110 (-1.515, -0.705) ^{††}
25 – 44 yrs	0.75	-1.062 (-1.283, -0.841) ^{††}	-1.051 (-1.298, -0.804) ^{††}
45 – 65 yrs	1.29	-0.457 (-0.672, -0.241) ^{††}	-0.440 (-0.677, -0.203) [†]
65 yrs or more	1.77	Ref.	Ref.
Sex			
Male	1.49	0.610 (0.472, 0.748) ^{††}	0.281 (0.078, 0.484) [*]
Female	0.89	Ref.	Ref.
Race			
White	1.18	Ref.	Ref.
Other	0.98	-0.291 (-0.832, 0.249)	0.274 (-0.245, 0.792)
Education			
Less than high school	1.95	Ref.	Ref.
High school graduate or equivalent	1.57	-0.189 (-0.867, 0.489)	0.434 (-0.209, 1.078)
Some college	1.23	-0.703 (-1.328, -0.078) [*]	-0.001 (-0.593, 0.590)
College grad or more	1.10	-0.811 (-1.431, -0.190) [*]	-0.023 (-0.615, 0.569)
Income			
Less than \$15,000	0.99	Ref.	Ref.
\$15,000 - \$24,999	1.43	0.436 (-0.084, 0.957)	0.120 (-0.375, 0.614)
\$25,000 - \$39,999	1.03	0.071 (-0.392, 0.534)	0.113 (-0.340, 0.566)
\$40,000 or more	1.19	0.308 (-0.137, 0.753)	0.395 (-0.073, 0.862)
House construction year			
1978 or after	1.00	Ref.	Ref.
1950 to 1977	1.31	0.334 (0.168, 500) ^{††}	0.191 (0.017, 0.365) [*]
1949 or before	1.39	0.461 (0.201, 0.721) [†]	0.428 (0.155, 0.702) [*]
Living in the household			
Less than a year	0.74	Ref.	Ref.
1 to 5 years	1.05	0.332 (-0.221, 0.884)	-0.068 (-0.617, 0.483)

6 to 10 years	0.99	0.300 (-0.266, 0.867)	-0.030 (-0.085, 0.256)
More than 10 years	1.31	0.613 (0.064, 1.163)*	-0.250 (-0.917, 0.218)
House renovation/remodeling			
No renovation done	1.10	Ref.	Ref.
Currently undergoing renovation	1.01	- 0.134 (-0.401, 0.134)	-0.216 (-0.470, 0.037)
Done within the last 12 months	1.37	0.409 (0.033, 0.786)*	0.178 (-0.168, 0.525)
Done beyond the last 12 months	1.26	0.202 (0.033, 0.371)*	-0.046 (-0.209, 0.118)
Peeling paint or paint chips			
None	1.18	Ref.	
Yes	1.15	0.054 (-0.214, 0.322)	
Current lead-related occupation			
No	1.16	Ref.	Ref.
Yes	1.45	0.412 (0.159, 0.665)*	0.215 (-0.020, 0.450)
Previous lead-related occupation			
No	1.11	Ref.	Ref.
Yes	1.36	0.250 (0.093, 0.407)*	-0.149 (-0.324, 0.026)
Current lead-related hobbies			
No	0.88	Ref.	Ref.
Yes	1.38	0.611 (0.484, 0.738)††	0.338 (0.172, 0.504)††
Previous lead-related hobbies			
No	1.13	Ref.	
Yes	1.21	-0.037 (-0.120, 0.120)	
Household members with lead-related occupations			
No	1.02	Ref.	Ref.
Yes	1.22	0.241 (0.061, 0.421)*	-0.074 (-0.239, 0.091)
Household members with lead-related hobbies			
No	1.09	Ref.	Ref.
Yes	1.29	0.292 (0.128, 0.456)†	0.151 (-0.021, 0.324)
Consumes wild game			
No	0.84	Ref.	Ref.
Yes	1.27	0.428 (0.313, 0.543)††	0.300 (0.157, 0.443)††

Ref. – Reference category; *p-value <0.05; †p-value <0.001; ††p-value <0.0001

Table 9: Multivariate- adjusted association between PbB and frequency, proportion, and duration of wild game consumption by game type¹

Variables	Venison (N=584)	Other game (N=378)	Birds (N=494)
	Parameter estimates (95% CI)	Parameter estimates (95% CI)	Parameter estimates (95% CI)
Consumption in a given year			
Occasionally	Ref.	Ref.	Ref.
Hunting season only	-0.012 (-0.536, 0.512)	0.072 (-0.276, 0.419)	0.156 (-0.064, 0.376)
All year round	0.005 (-0.267, 0.278)	-0.010 (-0.331, 0.312)	0.151 (-0.116, 0.418)
Consumption in a given month			
<1 time /week	Ref.	Ref.	Ref.
1-3 times/week	0.079 (-0.143, 0.301)	-0.074 (-0.381, 0.234)	0.053 (-0.213, 0.319)
> 3 times/week	0.148 (-0.133, 0.429)	-0.191 (-0.705, 0.323)	0.015 (-0.643, 0.672)
Most recent consumption			
<1 month ago	Ref.	Ref.	Ref.
1-6 months ago	-0.184 (-0.481, 0.112)	-0.461 (-0.790, -0.133)*	-0.279 (-0.516, -0.042)*
>6 months ago	-0.336 (-0.663, -0.009)*	-0.380 (-0.727, -0.032)*	-0.362 (-0.64, -0.081)*
Most often processed			
Ground	Ref.	Ref.	Ref.
Not ground	0.045 (-0.207, 0.296)	0.124 (-0.137, 0.385)	0.136 (-0.354, 0.625)
Both	-0.026 (-0.219, 0.166)	0.083 (-0.249, 0.414)	0.081 (-0.611, 0.772)
Average serving			
<2 oz	Ref.	Ref.	Ref.
≥2 oz	0.099 (-0.146, 0.345)	0.403 (0.068, 0.738)*	0.234 (-0.013, 0.480)
Years of consumption			
< 1 year	Ref.	Ref.	Ref.
1-3 years	-0.075 (-0.948, 0.797)	0.514 (-0.129, 1.158)	0.021 (-0.500, 0.542)
4-10 years	-0.070 (-0.992, 0.853)	0.130 (-0.378, 0.649)	0.176 (-0.403, 0.754)
>10 years	-0.114 (-1.023, 0.794)	0.145 (-0.272, 0.562)	0.182 (-0.283, 0.646)

Ref. – Reference category; * p-value <0.05; † p-value <0.001; †† p-value <0.0001;

¹After adjusting for age, sex, race, age of housing, current and previous lead-related hobbies, current and previous lead related occupations, household member's with lead-related hobbies or occupation

Appendix 1:

North Dakota Lead Exposure Study

General instruction to interviewers

- Make sure to conduct this face to face interview at a time and place convenient to the participant.
- Read all the questions distinctly. If the participant has difficulty in understanding the question, repeat the question or try to explain it with provided definitions, if available. Try to avoid giving your own interpretation of the question.
- Use a proxy respondent for any participant under the age of 18 years. A proxy respondent can be a parent, primary caregiver, grandparent, sibling or any other family member 18 years of age or older.
- Try to obtain any contact information in case the interview is incomplete or in case you need to call back for more information.
- *Italic* fonts are used for instruction purposes only. Do not read them aloud.
- **Bold** fonts are headers/sub-headers. Do not read them aloud.
- CAPITAL fonts are used for definitions/explanations. Read these if the participant has trouble understanding any term or context.
- Assign a participant ID (e.g. NDXXXX) after they have signed an informed consent. Parents or primary caregivers should also sign consent form if the participant is 18 years or younger.
- Provide a copy of the informed consent to the participant.
- Read out **participant's name** where it says 'Participant'.

Interviewer Name: _____ Interview Date: __/__/__

Interview status: 1 Completed [date: __/__/__] 2 Not Completed

Participant Name: _____

Address _____:

City: _____ Zip: _____ Phone: (1) _____ (2) _____

Interviewee relationship to the participant: _____

Start Survey:

"Thank you for agreeing to be in our study. I would like to ask you a few questions regarding your /participant's consumption of wild game such as deer, pheasant, elk, and other hunted animals, your/ participant's housing, your occupation and issues that can assist us in this lead exposure investigation. This survey will not take more than 15-20 minutes. I will ask you a question and give you some options to choose from. If you have any questions or don't understand what is being asked, please feel free to stop me. You can choose not to answer any question in this survey. All the information you give including your name, address, and your lead results will be kept confidential. Do you have any questions before we start?

(If 'no') I would like to start by asking you about yourself."

Section 1: Demographic information

Q1. What is your/ participant's sex? 1 Male 2 Female

Q2. What is your/participant's age?
 _____Years _____Months 99 Don't know 77 Refused

(If answer is 'Don't know' or 'Refused', ask Q3, otherwise skip to Q4)

Q3. You can also choose from the following categories:

- | | | |
|---|---|---|
| 1 <input type="checkbox"/> 2 to 5 years | 2 <input type="checkbox"/> 6 to 14 years | 3 <input type="checkbox"/> 15 to 24 years |
| 4 <input type="checkbox"/> 25 to 34 years | 5 <input type="checkbox"/> 35 to 44 years | 6 <input type="checkbox"/> 45 to 54 years |
| 7 <input type="checkbox"/> 55 to 64 years | 8 <input type="checkbox"/> 65 years or more | |
| 99 <input type="checkbox"/> Don't know | 77 <input type="checkbox"/> Refused | |

Q4. Do you consider yourself/participant to be of Hispanic or Latino origin?
 1 Hispanic or Latino 2 Not Hispanic or Latino
 99 Don't know 77 Refused

Q5. What race best describes you/participant?

 1 White 2 Black or African American
 3 Asian 4 Native Hawaiian or other Pacific Islander
 5 American Indian or Alaskan native 6 Other: _____
 99 Don't know 77 Refused

Q6. What is your highest level of education (*List education level of proxy if participant <18 years of age*)?

- | | | |
|--|--|---|
| 1 <input type="checkbox"/> Less than HS graduate | 2 <input type="checkbox"/> HS graduate or equivalent | 3 <input type="checkbox"/> Some college |
| 4 <input type="checkbox"/> College grad or more | 99 <input type="checkbox"/> Don't know | 77 <input type="checkbox"/> Refused |

Q7. What is your/participant's annual household income?

- | | | |
|---|--|--|
| 1 <input type="checkbox"/> less than \$15,000 | 2 <input type="checkbox"/> \$15-\$24,999 | 3 <input type="checkbox"/> \$25-\$39,000 |
| 4 <input type="checkbox"/> \$40,000 or more | 99 <input type="checkbox"/> Don't know | 77 <input type="checkbox"/> Refused |

NOTES TO INTERVIEWER

Has any other member(s) of the participant's household already completed this survey?

- 1 Yes (*ID of any at least one participating household member: ND_ _ _ _*)
2 No

(If 'yes', go to section 3, p.4. Otherwise continue with section 2)

Section 2: Housing information

"Now I will ask you a few questions about the house that you/participant live in or consider to be your primary residence."

PRIMARY RESIDENCE: PRIMARY RESIDENCE IS THE PLACE WHERE THE YOU/PARTICIPANT SPEND AT LEAST FOUR NIGHTS A WEEK.

Q8. Do you know what year that house/apartment was built?

Year of construction (*Skip to Q10*)

99 *Don't know (Continue to Q9)*

Q9. Which of the following categories do you think most closely matches the year of construction?

1 1978 and after 2 1950 to 1977 3 Before 1949

99 *Don't know* 77 *Refused*

Q10. How long have you/participant been living in this house/apartment?

Number

1 Years

2 Months (*record 1 month if it has been less than a month*)

99 *Don't know* 77 *Refused*

Q11. Has this house/apartment undergone renovation or is it currently undergoing renovation or remodeling? Renovation and remodeling can include the removal of walls, replacement of windows, or paint removal, etc.

1 Currently undergoing renovation/remodeling

2 Renovation/remodeling done within the last twelve months

3 Renovation/remodeling done more than twelve months ago

4 Never been renovated/remodeled

99 *Don't know* 77 *Refused*

Q12. Is there any peeling paint or paint chips in this house/apartment? (*Check all that apply*)

1 No 2 Yes, interior 3 Yes, exterior

99 *Don't know* 77 *Refused*

Q13. Is this house/apartment near a lead smelter, lead mine, battery recycling plant, or any other industry that is likely to release lead in to the environment?

1 No 2 Yes, within 1 mile 3 Yes, within 1-5 miles

4 Yes, but more than 5 miles away 99 *Don't know* 77 *Refused*

Section 3: Blood lead test history

Q14. Have you/participant ever had a blood test for lead?

1 Yes 2 No 99 Don't know 77 Refused

(If 'yes', ask Q15 and Q16. Otherwise, skip to section 4)

Q15. Have you/participant ever been told that you have high or elevated blood lead levels that can be harmful for your/participant's health?

1 Yes 2 No 99 Don't know 77 Refused

Q16. Do you/participant know the results from your/ participant's most recent blood lead test?

1 Yes 2 No 77 Refused

(If 'yes') Levels: _____ Unit: _____ Date tested: __/__/__ or _____ months ago

Section 4: Exposure history

(Ask Q17 if the study participant is 18 years of age or older, otherwise, go to Q18)

Q17. Were you/participant ever engaged in any of the occupations listed on this card?

(Present participant with the occupation card and choose one answer option)

1 Yes, now 2 Yes, previously 3 No 99 Don't know 77 Refused

Occupation	Answer (write #)	Occupation	Answer (write #)
1. Auto repair		9. Lead smelter, refinery, mine	
2. Battery manufacture/repair		10. Military/Police officer	
3. Brass/copper foundry		11. Plastic, glass, ceramic, or rubber industry	
4. Chemical industry		12. Plumbing, pipe fitting	
5. Computer printing		13. Radiator repair	
6. Construction		14. Welding	
7. Gas station attendant		88. Other: _____	
8. Home construction/painting			

Q18. Has anyone else in the household ever been engaged in any of the occupations listed on the card?

1 Yes 2 No 99 Don't know 77 Refused

Section 4: Contd.

Q19. Have you/participant ever had any of the hobbies listed on this card?

(Present participant with the hobbies card and choose one answer option)

1 Yes, now 2 Yes, previously 3 No 99 Don't know 77 Refused

Hobbies	Answer (write one)	Hobbies	Answer (write one)
1. Car/boat repair		8. Lead soldering	
2. Casting (bullets, fishing weights, etc.)		9. Pottery/stained glass making	
3. Casting lead figures (toys, soldiers)		10. Reloading	
4. Furniture finishing		11. Target shooting	
5. Home remodeling/paint job		12. Welding	
6. Hunting		88. Other:	
7. Jewelry making		_____	

Q20. Has anyone else in the household ever been engaged in any of the hobbies listed on the card?

1 Yes 2 No 99 Don't know 77 Refused

Q21. Do you/participant use any traditional Asian cosmetics, for example: Surma, Kohl, Sindoor?

1 Yes 2 No 99 Don't know 77 Refused

Q22. Do you/participant use any herbal or folk remedies, for example: greta, azarcon, pay-loo-ah, ayurvedic products?

1 Yes 2 No 99 Don't know 77 Refused

Q23. Have you/participant ever traveled to or lived in South or Central America or Mexico?

1 Yes 2 No 99 Don't know 77 Refused

Q24. Do you/participant use ceramic or glazed pottery made in South or Central America or Mexico for cooking, eating, or drinking?

1 Yes 2 No 99 Don't know 77 Refused

Q25. Do you/participant eat venison or other game meat or birds (other than water fowl) that are hunted using firearms? *(Check all that apply)*

1 Venison 2 Other game meat 3 Birds (other than water fowl)
 4 No 99 Don't know 77 Refused

(if 'No', 'Don't know' or 'Refused' then go to Section 5, otherwise continue)

Section 4: Contd.

Question	Venison	Other game meat	Birds(other than water fowl)
Q26. In a given year, how often do you/participant eat these kinds of meat?	1 <input type="checkbox"/> Occasionally 2 <input type="checkbox"/> Hunting season only 3 <input type="checkbox"/> Year round 99 <input type="checkbox"/> Don't know 77 <input type="checkbox"/> Refused	1 <input type="checkbox"/> Occasionally 2 <input type="checkbox"/> Hunting season only 3 <input type="checkbox"/> Year round 99 <input type="checkbox"/> Don't know 77 <input type="checkbox"/> Refused	1 <input type="checkbox"/> Occasionally 2 <input type="checkbox"/> Hunting season only 3 <input type="checkbox"/> Year round 99 <input type="checkbox"/> Don't know 77 <input type="checkbox"/> Refused
Q27. How often do you/participant eat these kinds of meat in a given month?	1 <input type="checkbox"/> <1/wk 2 <input type="checkbox"/> 1-3 times/wk 3 <input type="checkbox"/> > 3 times/wk 99 <input type="checkbox"/> Don't know 77 <input type="checkbox"/> Refused	1 <input type="checkbox"/> <1/wk 2 <input type="checkbox"/> 1-3 times/wk 3 <input type="checkbox"/> > 3 times/wk 99 <input type="checkbox"/> Don't know 77 <input type="checkbox"/> Refused	1 <input type="checkbox"/> <1/wk 2 <input type="checkbox"/> 1-3 times/wk 3 <input type="checkbox"/> > 3 times/wk 99 <input type="checkbox"/> Don't know 77 <input type="checkbox"/> Refused
Q28. When was the last time you/participant ate these kinds of meat?	1 <input type="checkbox"/> <1 a month ago 2 <input type="checkbox"/> 1-6 months ago 3 <input type="checkbox"/> > 6 months ago 99 <input type="checkbox"/> Don't know 77 <input type="checkbox"/> Refused	1 <input type="checkbox"/> <1 a month ago 2 <input type="checkbox"/> 1-6 months ago 3 <input type="checkbox"/> > 6 months ago 99 <input type="checkbox"/> Don't know 77 <input type="checkbox"/> Refused	1 <input type="checkbox"/> <1 a month ago 2 <input type="checkbox"/> 1-6 months ago 3 <input type="checkbox"/> > 6 months ago 99 <input type="checkbox"/> Don't know 77 <input type="checkbox"/> Refused
Q29. How is the meat most often processed?	1 <input type="checkbox"/> Ground 2 <input type="checkbox"/> Not ground 99 <input type="checkbox"/> Don't know 77 <input type="checkbox"/> Refused	1 <input type="checkbox"/> Ground 2 <input type="checkbox"/> Not ground 99 <input type="checkbox"/> Don't know 77 <input type="checkbox"/> Refused	1 <input type="checkbox"/> Ground 2 <input type="checkbox"/> Not ground 99 <input type="checkbox"/> Don't know 77 <input type="checkbox"/> Refused
Q30. How do you/family most often cook your meat?	1 <input type="checkbox"/> Stew 2 <input type="checkbox"/> Barbecue/grill 3 <input type="checkbox"/> Bake/roast 4 <input type="checkbox"/> Fry 5 <input type="checkbox"/> Other 99 <input type="checkbox"/> Don't know 77 <input type="checkbox"/> Refused	1 <input type="checkbox"/> Stew 2 <input type="checkbox"/> Barbecue/grill 3 <input type="checkbox"/> Bake/roast 4 <input type="checkbox"/> Fry 5 <input type="checkbox"/> Other 99 <input type="checkbox"/> Don't know 77 <input type="checkbox"/> Refused	1 <input type="checkbox"/> Stew 2 <input type="checkbox"/> Barbecue/grill 3 <input type="checkbox"/> Bake/roast 4 <input type="checkbox"/> Fry 5 <input type="checkbox"/> Other 99 <input type="checkbox"/> Don't know 77 <input type="checkbox"/> Refused
Q31. In an average serving, how much meat do you/participant eat?	1 <input type="checkbox"/> < 2 oz. 2 <input type="checkbox"/> ≥2 oz. 99 <input type="checkbox"/> Don't know 77 <input type="checkbox"/> Refused	1 <input type="checkbox"/> < 2 oz. 2 <input type="checkbox"/> ≥2 oz. 99 <input type="checkbox"/> Don't know 77 <input type="checkbox"/> Refused	1 <input type="checkbox"/> < 2 oz. 2 <input type="checkbox"/> ≥2 oz. 99 <input type="checkbox"/> Don't know 77 <input type="checkbox"/> Refused
(2 oz. IS EQUIVALENT TO HALF OF A QUARTER POUNDER HAMBURGER FROM McDonalds)			
Q32. How many years have you/participant been eating these kinds of meat?	1 <input type="checkbox"/> < 1 year 2 <input type="checkbox"/> 1-3 years 3 <input type="checkbox"/> 4-10 years 4 <input type="checkbox"/> > 10 years 99 <input type="checkbox"/> Don't know 77 <input type="checkbox"/> Refused	1 <input type="checkbox"/> < 1 year 2 <input type="checkbox"/> 1-3 years 3 <input type="checkbox"/> 4-10 years 4 <input type="checkbox"/> > 10 years 99 <input type="checkbox"/> Don't know 77 <input type="checkbox"/> Refused	1 <input type="checkbox"/> < 1 year 2 <input type="checkbox"/> 1-3 years 3 <input type="checkbox"/> 4-10 years 4 <input type="checkbox"/> > 10 years 99 <input type="checkbox"/> Don't know 77 <input type="checkbox"/> Refused
<p>Q33. Where do you get your wild game meat? (Check all that apply)</p> <p>1 <input type="checkbox"/> Food Pantries or similar 2 <input type="checkbox"/> Hunting (self/family/friends) 3 <input type="checkbox"/> Other sources</p> <p>99 <input type="checkbox"/> Don't know 77 <input type="checkbox"/> Refused</p> <p>(If answer to Q33 is 'Hunting' or 'Other sources' then ask Q34, else go to the next section)</p> <p>Q34. Who processes your meat? (Check all that apply)</p> <p>1 <input type="checkbox"/> Self or family member 2 <input type="checkbox"/> Meat packers/processors/lockers 3 <input type="checkbox"/> Butcher</p> <p>99 <input type="checkbox"/> Don't know 77 <input type="checkbox"/> Refused</p>			

Section 4: Contd.

(If answer to Q34 is 'Self or family member' then ask Q35, else go to the next section)

Q35. Do you/family member remove the meat around the wound channel before cooking the meat?

1 Yes 2 No 99 Don't know 77 Refused

Section 5: Child section (Ask only if the child is <6 years of age; otherwise go to Section 6)

Q36. Does the child frequently visit (2 or more times a week) a home or a building (second home, relatives, school, or day care) built before 1978?

1 Yes 2 No 99 Don't know 77 Refused

(If 'yes', then ask Q37, otherwise skip to Q38)

Q37. Has that home or building recently been, or is currently being renovated or remodeled?

1 Yes 2 No 99 Don't know 77 Refused

Q38. Does the child frequently visit, or temporarily live with, a person who has/had any of the above mentioned hobbies or occupation? *(Present the occupation and hobbies cards again)*

1 Yes 2 No 99 Don't know 77 Refused

(If 'yes', then list all that apply) 1 Hobby (#s): _____ 2 Occupation (#s): _____

Q39. Does the child often pick up things from the ground and put them in his/her mouth?

1 Yes 2 No 99 Don't know 77 Refused

Section 6: Assessment of pregnant participants (For female respondents between 18-45 years of age; otherwise end survey and read "End Script")

Q40. Are you currently pregnant?

1 Yes 2 No 77 Refused

(If 'no', end survey and read 'End script')

Q41. People sometimes consume non-food items during pregnancy. Have you consumed non-food items such as clay, chalk, dirt, etc. during your pregnancy?

1 Yes 2 No 99 Don't know 77 Refused

Q42. During your pregnancy, have you been told that you are anemic (low number of red blood cells)?

1 Yes 2 No 99 Don't know 77 Refused

End Script:

"Thank you again for your time and participation. The information you have given is very important and will help us answer our very important question regarding lead and wild game consumption. As we mentioned earlier, we will now draw a little blood from you/participant. The result of this blood draw and the investigation will be communicated to you as soon as possible. If you have any questions about today's survey, please contact Dr. Kirby Kruger at the State Health Department at 701.328.2378.

Comments:

(List anything you found to be relevant to the investigation during the whole encounter)
