Individual and environmental risk factors for high blood lead concentrations in Danish indoor shooters

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ABSTRACT

INTRODUCTION: International studies have shown blood lead at levels causing health concern in recreational indoor shooters. We hypothesized that Danish recreational indoor shooters would also have a high level of blood lead, and that this could be explained by shooting characteristics and the physical environment at the shooting range.

MATERIAL AND METHODS: This was an environmental case study of 58 male and female shooters from two indoor shooting ranges with assumed different ventilation and cleaning conditions. Information was obtained on general conditions including age, gender, tobacco and alcohol use, and shooting conditions: weapon type, number of shots fired, frequency of stays at the shooting range and hygiene habits. A venous blood sample was drawn to determine blood lead concentrations; 14 non-shooters were included as controls.

RESULTS: Almost 60% of the shooters, hereof five out of 14 women, had a blood lead concentration above 0.48 micromol/l, a level causing long-term health concern. All controls had blood lead values below 0.17 micromol/l. Independent significant associations with blood lead concentrations above 0.48 micromol/l were found for shooting at a poorly ventilated range, use of heavy calibre weapons, number of shots and frequency of stays at the shooting range.

CONCLUSION: A large proportion of Danish recreational indoor shooters had potentially harmful blood lead concentrations. Ventilation, amounts of shooting, use of heavy calibre weapons and stays at the shooting ranges were independently associated with increased blood lead.

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TRIAL REGISTRATION: The Danish Regional Capital Scientific Ethics Committee approved the study, protocol number H-4-2010-130.

Lead is a well-known toxic agent, and measures to reduce human lead exposure have been numerous and largely effective. However, ammunition used at indoor shooting ranges remains a significant source of lead exposure due to lead from barrel-projectile friction, projectile endplate fragmentation and percussion cap ignition [1-4]. A number of recent international studies have shown that blood lead concentrations (B-Pb) among recreational and professional indoor shooters frequently exceed threshold limit values for individuals occupationally exposed to lead. Few Danish studies have touched upon this subject; the most recent from 1979 showed that nine shooting range instructors from three different ranges had been exposed to lead [1-6]. Results from the literature support that ventilation system function and shooting range cleaning procedures are associated with B-Pb, whereas individual behaviour has only been studied to a limited extent; some evidence of an association with B-Pb may warrant a more extensive elucidation of potential individual risk factors [3, 4, 7].

Reversible neurotoxic effects of lead seem to be present in adults at B-Pb below 0.96 micromol/l [8], and there is some evidence to suggest an increased cardiovascular mortality at B-Pb below 0.48 micromol/l [9]. According to the European Food Safety Authority, there is no evidence to support a B-Pb threshold for a number of critical endpoints including developmental neurotoxicity and renal effects in adults [10]. Negative effects on intellectual development in infancy have been demonstrated at a B-Pb below 0.48 micromol/l and a "no effect" level remains to be identified [11, 12]. In the context of shooting-related lead exposure, female shooters may constitute a particularly vulnerable group as lead is transferred transplacentally. The United States' Centre for Disease Control and Prevention recommends preventive action and follow-up of pregnant women with a B-Pb above 0.24 micromol/l [13]. The Danish occupational biological threshold limit for B-Pb is 0.96 micromol/l, which may be insufficient in case of long-term exposure, and work-related lead exposure among pregnant women is not tolerated [14].

The Danish Rifle Association has approximately 70,000 members who are potentially exposed to lead as recreational shooters. Despite this, only few Danish studies have approached the subject and none have systematically evaluated shooting-related exposure [6]. We hypothesized that also Danish recreational shooters would have a high concentration of blood lead depending on shooting characteristics and the physical environment of the shooting range.

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TABLE 1

Distribution of demographic characteristics and blood lead concentrations for Range A and Range B, female shooters and the reference group.

	All shooters	Range A	Range B	Female shooters	Reference group
n	58	29	29	14	14
Age, mean (range), years	48.8 (18-74)	51.1 (19-68)	46.6 (18-74)	41.2 (20-57)	52.9 (35-63)
Males, %	75.9	79.3	72.4	–	71.4
B-Pb, median (range), micromol/l	0.56 (< 0.07-1.61)	0.85 (0.18-1.61)	0.46 (< 0.07-1.32)	0.43 (< 0.07-1.41)	0.08 (< 0.07-0.16)
B-Pb distribution, %					
< 0.17 micromol/l	3	–	3	7	100
0.17-0.47 micromol/l	38	31	48	50	–
0.48-0.95 micromol/l	28	24	31	36	–
≥ 0.96 micromol/l	30	45	17	7	–

B-Pb = blood lead concentration.

TABLE 2

Bivariate analyses of the relationship between socio-demographic factors (gender and age), lifestyle and shooting-related characteristics and blood lead concentration among the 58 shooters. Significant p-values are in italics.

	Blood lead concentration, micromol/l			
	median	min.	max.	p-value
Socio-demographic factors				
Gender				*0.01*[a]
Male (n = 44)	0.61	0.18	1.61	
Female (n = 14)	0.28	< 0.07	1.41	
Age				0.20[a]
Youngest half (n = 29)	0.50	< 0.07	1.61	
Oldest half (n = 29)	0.62	0.18	1.51	
Lifestyle factors				
Alcohol consumption, units (12 g of alcohol)/week				0.33[b]
0 (n = 10)	0.87	< 0.07	1.61	
1-21 for males/1-14 for females (n = 44)	0.55	0.17	1.54	
> 21 for males/ > 14 for females (n = 4)	0.46	0.24	0.59	
Active smoker				0.34[a]
No (n = 42)	0.60	< 0.07	1.61	
Yes (n = 16)	0.48	0.17	1.54	
Shooting-related factors				*0.02*[a]
Shooting range				
Range A (n = 29)	0.85	0.18	1.61	
Range B (n = 29)	0.46	< 0.07	1.32	
Total calibre 0.22 weapons[c], monthly shots fired				*0.004*[b]
< 150 (n = 16)	0.46	< 0.07	1.23	
150-249 (n = 25)	0.56	0.18	1.61	
≥ 250 (n = 17)	0.68	0.23	1.41	
Use of heavy-calibre weapons				*0.02*[a]
No, (n = 43)	0.50	< 0.07	1.54	
Yes (n = 15)	0.96	0.24	1.61	
Shooter and instructor				
Yes (n = 8)	0.85	0.37	1.41	0.09[a]
No (n = 50)	0.52	< 0.07	1.61	
Shooting range visits (all ranges), monthly				*0.01*[b]
< 5 (n = 13)	0.37	< 0.07	1.61	
5-9 (n = 21)	0.47	0.19	1.51	
10-15 (n = 14)	0.58	0.20	1.41	
> 15 (n = 10)	0.92	0.35	1.28	
Shooting hygiene				
Hand-washing after shooting				0.29[a]
Never/rarely (n = 19)	0.62	0.19	1.61	
Always/often (n = 39)	0.54	< 0.07	1.41	

a) Mann-Whitney rank sum test; b) Spearman correlation analysis; c) Pistol and rifle.

MATERIAL AND METHODS

Two Danish indoor shooting ranges, referred to in the Tables as Range A and Range B, were included in the study. Their selection was based on the assumption that the facilities of Range A enjoyed a high technical standard, including an up-to-date ventilation system, while the technical standards of Range B were inadequate. In order to de facto evaluate the standard of the two ranges, a technical check was performed of the actual situation – including ventilation air speed at the stands (air speed), lead surface concentrations throughout club premises and adequacy of the cleaning procedures.

Participants were members of the two shooting clubs. A convenience sample of 50 persons aged 18-65 years from each club were invited to participate in the study. Participants were only included if they had been shooting for the three preceding years and had no known lead exposure besides shooting. A total of 75 persons volunteered of whom 29 were from Range B; the same number of participants was therefore selected from Range A with the aim of achieving two reasonably comparable groups with respect to gender, age, recent and prior shooting activity and predominant weapon of choice. Fourteen hospital employees were selected as a reference group. They were comparable to the shooters with respect to age and gender, but with no known lead exposure.

Information on risk factors was obtained via a questionnaire and validated at an interview. For each shooter, the information included socio-demographic, lifestyle, and shooting-related factors. All questionnaire data significantly associated with high blood lead levels are presented in **Table 1** and **Table 2** along with a selection of relevant, but non-significant questionnaire data. Data not presented in table form included occupation and leisure activities not related to shooting, seniority as a shooter, use of capped or unleaded ammunition, use of gloves during weapons cleaning and frequency hereof, food/beverage consumption and smoking on club premises, surface and bullet stop cleaning, and casting of lead projectiles. Blood lead sampling was done simultaneously with the interview. Examinations were performed in the spring of 2011 outside shooting premises in order to avoid contamination of the specimens.

For determination of B-Pb, 6 ml of venous blood was drawn using a BD Vacutainer Trace Element ethylene diamine tetra acetate (EDTA) tube designed for metal trace determination. Sampling was performed with attention to minimal stasis. The blood samples were stored in a refrigerator until analysis at a certified Danish laboratory using electrothermal atomic absorption with the Zeeman background correction technique. The lower limit of detection was 0.07 micromol/l.

Statistical analysis

In Table 1 and Table 2, B-Pb are presented as median values and ranges. Associations between risk factors and B-Pb were tested using the Spearman non-parametric correlation analysis and the Mann-Whitney rank sum test. B-Pb were subsequently dichotomized into two groups: above and below 0.48 micromol/l; and multiple logistic regression analysis with stepwise backward elimination was used to identify independent determinants for B-Pb above 0.48 micromol/l, presenting factors with odds ratios and 95% confidence intervals (**Table 3**). SPSS version 19 was used. For all analyses, a two-sided p value < 0.05 was considered statistically significant.

Trial registration: The Danish Regional Capital Scientific Ethics Committee approved the study, protocol number H-4-2010-130.

RESULTS

Table 1 provides an overview of overall shooter and reference group characteristics. On average, shooters at Range B were five years younger than those at Range A and reference group individuals. The proportion of male shooters at Range A was approximately 80%; at Range B and in the reference group, it was around 70%. Shooting was the only relevant lead exposure. Overall, the median B-Pb was 0.56 micromol/l, ranging from < 0.07 micromol/l (below detection level) to 1.61 micromol/l.

TABLE 3

Multivariate analysis of the association between socio-demographic factors, lifestyle and shooting-related characteristics and high blood lead concentrations defined as concentrations above 0.48 micromol/l among the 58 shooters. Multiple logistic regression analysis with stepwise backward elimination of variables indicating odds ratios with 95% confidence intervals for belonging to the group with high blood level concentrations. The factors are ranked by the strength of statistical association with elevated blood level concentrations.

	OR (95% CI)	p-value
Factors in the end model		
Range: A versus B	13.1 (1.9-91.4)	0.009
Heavy calibre vs. not	17.8 (1.9-170.0)	0.01
Calibre 0.22 weapon, monthly shots		
< 150	1[a]	0.06
150-249	8.3 (1.2-58.1)	0.03
≥ 250	14.0 (1.3-151.4)	0.03
Shooting range visits, monthly		
< 5	1[a]	0.06
5-9	1.6 (0.2-11.0)	0.66
10-15	7.7 (0.8-78.0)	0.08
> 15	51.3 (1.7-1511.0)	0.02
Excluded from the end model (p > 0.05)		
Gender, instructor	–	–

CI = confidence interval; OR = odds ratio.
a) Reference category

Lead exposure at indoor shooting ranges.

The median B-Pb was 0.85 micromol/l at Range A and 0.46 micromol/l at Range B. The proportion of shooters with a B-Pb above 0.96 micromol/l was 45% at Range A and 17% at Range B. Among female shooters, six had a B-Pb above 0.48 micromol/l, seven between 0.17 and 0.48 micromol/l and one below 0.17 micromol/l. Median and average B-Pb in the reference group was 0.08 micromol/l and all individuals had B-Pb values below 0.17 micromol/l.

Table 2 shows risk factors associated with B-Pb in the bivariate analyses. Gender, shooting range, total number of monthly shots using calibre 0.22 weapons, periodical firing of heavy calibre weapons (0.32 and above) and number of monthly shooting range visits were all statistically significantly associated with increased B-Pb. Age, smoking, alcohol intake, hand-washing after shooting and being a shooting instructor showed no statistically significant association with B-Pb, although there was a tendency towards a higher B-Pb among shooting instructors. The majority (24 out of 28) of shooters who used air guns also used gunpowder-propelled weapons. Among the four shooters exclusively using airguns, B-Pb were 0.51 (instructor), 0.21, 0.18 and below 0.07 micromol/l.

Table 3 shows the result of a multiple logistic regression analysis, including risk factors that were significantly or nearly significantly ($p < 0.10$) associated with B-Pb in the bivariate analyses presented in Table 2. Four of the six factors were significantly associated with having a B-Pb above 0.48 micromol/l: the shooting range attended, use of heavy calibre ammunition, number of shots using calibre 0.22 weapons and number of visits to the shooting range. With respect to the two latter factors, a clear dose-response relationship was observed. Gender was not independently associated with a B-Pb above 0.48 micromol/l, and being an instructor remained insignificant as in bivariate analyses, Table 2.

Technical evaluation

Air speed at the stands was well below 0.1 m per second at both shooting ranges. Due to an unexpected faulty ventilation system construction at Range A, contaminated air was recycled. Traces of lead were detected on all examined surfaces in both club premises, both on and outside the shooting range, and lead surface concentration increased with closeness to the shooting range stands. None of the two ranges had documented regular maintenance procedures or washable surfaces at the stands.

DISCUSSION

This environmental case study demonstrates that, in a Danish setting, recreational indoor shooters have high B-Pb. Their raised B-Pb could be attributed to the quality of ventilation at the shooting range and individual factors such as type of weapon used, the amount fired and frequency of stays at the shooting range. Our study showed that 30% of all participating shooters had a B-Pb above 0.96 micromol/l and that 60% had a B-Pb above 0.48 micromol/l. Women had a lower B-Pb than men. Still, five out of 14 women had a B-Pb above 0.48 micromol/l and one exceeded 0.96 micromol/l. Among the few shooters only using air guns, B-Pb were at a level approaching that of the reference group.

The low B-Pb in the control sample of non-shooters is consistent with the results from recent international surveys of population blood lead showing a declining B-Pb over the past decades [15, 16]. The latest Danish survey was performed in the 1990s and showed a mean B-Pb of 0.17 micromol/l [17]. The median B-Pb among shooters was ten times (Range A) and six times (Range B) that of the non-shooters in the present study.

Airflow at the stands was below 0.1 m per second at both shooting ranges, but should not be below 0.25 m pr. second [18]. Thus, in that respect, the ventilation system function was inadequate at both shooting ranges. Accordingly then, our a priori assumption regarding any superiority of the technical facilities at Range A unfortunately did not hold true. The difference in median B-Pb between the two groups of shooters likely originates from the dysfunctional ventilation system with recirculation of contaminated air at Range A. This difference and the association between B-Pb and the number of shots fired and increasing weapon calibre suggests that inhalation of airborne lead dust is a key risk factor. Many shots fired, however, also entail a longer stay around the shooting stands which involves a risk of exposure to the highest level of secondary environmental contamination from surfaces.

Stay in shooting range premises was an independent determinant of B-Pb above 0.48 micromol/l, and as such not affected by shooting frequency or type of weapon used, which indicates that secondary contamination from surfaces is also a source of exposure. Hand-washing after shooting was not associated with a low median B-Pb, perhaps because renewed contamination of the hands from lead-contaminated surfaces throughout club premises allowed for continued exposure by hand to mouth activity.

Albeit not statistically significant, the higher median B-Pb among shooting instructors makes sense because they are close to the shooting stands during firing and are exposed to both primary and secondary contamination. We could not confirm earlier findings of age, gender and alcohol intake as risk factors for a high B-Pb [15, 17]. A limited number of participants and the rather powerful effect of the shooting may have masked such associations.

At least one prior study indicated that a well-functioning ventilation system and wet surface cleaning can ensure that shooters' blood lead is at an acceptable level [4]. Experience from the working environment indicates that improved hygiene pertaining to hand-washing, smoking and other hand-mouth activity can reduce exposure [19, 20]. Earlier findings that lead exposure can be reduced by using smaller calibre weapons, including airguns, concerts with the present data on large calibre weapons, calibre 0.22 and airguns although data on airguns are insufficient [1].

Lead exposure in fertile women is a particular problem as B-Pb is reflected in the foetus during pregnancy. Intellectual impairment is observed at B-Pb below 0.48 micromol/L and a safe lower limit has not been established. [11, 12] In this study, only six out of the 14 women included had B-Pb under 0.24 micromol/l as recommended by the Centre for Disease Control and Prevention.

CONCLUSION

This study detected a high prevalence of B-Pb above the minimum level causing long-term health concern in a group of Danish recreational indoor shooters. This finding is in line with prior international results. Inadequate ventilation, number of shots, high-calibre weapons and probably widespread secondary contamination at shooting ranges all seemed to be associated with a raised B-Pb. Considering the substantial number of indoor shooters nationwide, the results of this study calls for preventive action to reduce lead exposure. Especially for female shooters, it is pertinent to reduce the level of exposure. The study also indicates a need for further epidemiological study of the risk factors for lead exposure in indoor shooters in order to substantiate the limited number of studies at present and the effects of interventions.

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