

# Lead Exposures Among Recreational Shooters



Rapid evidence review  
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## Authors

Dru Sahai, MSc(A), ROH, CPHI(C), CRSP  
Environmental Health Science Specialist  
Environmental and Occupational Health  
Public Health Ontario

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## BACKGROUND

A health care practitioner notified a local health unit after seeing an asymptomatic 70 year old male patient with a blood lead level (BLL) of 12 µg/dL (0.61 µmol/L<sup>1</sup>). The patient reported that he shoots twice weekly at an indoor firing range operated by volunteers.

Public Health Ontario (PHO) was asked to “review the patient’s BLL and provide advice on the significance of the results relative to expected background levels”. As a result of this advice, a lead exposure assessment of the firing range was initiated by the health unit.

PHO was also asked to provide advice on performing the assessment and recommended sampling for potential sources of lead exposure, including air and surface (vacuum and surface wipe) samples be performed.

Results from the exposure assessment found that four of the five breathing zone samples performed on shooters [task-based time-weighted average (TWA) lead concentrations ranged from 3–147 µg/m<sup>3</sup> over the sampling periods (19–47 minutes)] exceeded Ontario’s occupational exposure limit of 50 µg/m<sup>3</sup> (8 hr TWA). This indicated the inadequacy of the existing ventilation system to reduce inhalable airborne lead generated during shooting. Wipe and vacuum samples showed the presence of lead on eight of the nine surfaces tested. Lead dust on surfaces inside a firing range can be easily transferred to hands, which can result in ingestion of lead through hand-to-mouth contact.

The current Canadian blood lead intervention level set by Health Canada is 10 µg/dL.<sup>1</sup> This is the level at which public health action is recommended to reduce exposure. However, Health Canada does note that there is evidence to indicate that chronic health effects do occur below 10 µg/dL, including neurodevelopmental, neurodegenerative, cardiovascular, renal, and reproductive effects.<sup>1</sup> In the US, the National Toxicology Program (NTP) has recently released a monograph on the health effects of low level lead exposure to adults, the conclusions of which are provided in Appendix A.

## PURPOSE AND RESEARCH QUESTIONS

The purpose of this review is to provide health units with evidence-based information on the potential lead exposure indoor recreational shooters can experience and what interventions can be taken to prevent such exposures.

In relation to potential lead exposure associated with recreational shooting, this review addresses the following research questions:

1. What is the evidence that recreational shooters are exposed to lead?

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<sup>1</sup> 1 micrograms per decilitre (µg/dL) = 0.0483 micromole per litre (µmol/L) OR 1 µmol/L = 20.7039 µg/dL

2. What is the evidence that recreational shooters can take home lead, thereby incidentally exposing their families?
3. What preventative measures can be instituted to reduce lead exposure?

The methods used for the literature search is provided in Appendix B.

## FINDINGS

### EXPOSURE TO LEAD

**Elevated blood lead levels in occupationally exposed workers at firing ranges are well documented.<sup>2-6</sup> Exposures can also occur at ranges run by volunteers where regulations related to worker protection may not apply. As many of these ranges may serve a social function, as well as providing a place to practice shooting, children as well as adults may be present.**

Lead is used in the manufacture of bullets and can be found in both the projectile and the primer.<sup>7-10</sup> Since the 1960s, firing ranges have been recognized as potential sources of lead exposure and lead absorption.<sup>5</sup> During shooting, airborne lead fumes and lead particles are generated by a) the ignition of lead-containing primers, b) the friction of bullets against the gun barrel, and c) the fragmentation that occurs as bullets strike the bullet trap.<sup>3</sup> Proper controls are required to limit exposure that can occur via inhalation of lead-containing dust and fumes as well as through the ingestion of lead particles from hand-to-mouth contact with contaminated surfaces.<sup>11</sup>

Elevated blood lead levels in occupationally exposed workers at firing ranges are well documented.<sup>2-6</sup> Exposures can also occur at ranges run by volunteers where regulations related to worker protection may not apply. Recently, reports about increased blood lead levels in recreational shooters have also appeared.<sup>7;8;10;12-14</sup> The Centers for Disease Control and Prevention (CDC) estimates that during the 2002–2012 period, non-work-related target shooting was the likely source of exposure for 2,673 of 9,044 persons with elevated BLLs (1,290 with BLLs  $\geq 25$   $\mu\text{g}/\text{dL}$  and 1,388 with BLLs of 10–24  $\mu\text{g}/\text{dL}$ ).<sup>14</sup>

No Ontario or Canada-based studies pertaining to lead exposure in recreational shooters were identified in the literature search for this review. The extent to which the findings from studies outside Ontario apply to Ontario's firing ranges is not clear, but they likely give some insights into problems that may exist and measures that could be employed to reduce exposures.

Following the detection of symptomatic lead toxicity in two competitive shooters, George et al. measured BLL in 52 competitive shooters from six target shooting clubs in New Zealand.<sup>15</sup> Forty-one shooters had BLL above the then reference range of 10 to 39  $\mu\text{g}/\text{dL}$  for males and 5.2 to 30  $\mu\text{g}/\text{dL}$  for females. The mean BLL was found to be 55  $\mu\text{g}/\text{dL}$  (46  $\mu\text{g}/\text{dL}$  for females and 58  $\mu\text{g}/\text{dL}$  for males). Air lead concentrations at one club run by volunteers ranged from 0.120  $\text{mg}/\text{m}^3$  to 0.210  $\text{mg}/\text{m}^3$ . Samples of dust from surfaces in this club contained high levels of lead. Shooters at this range did not wear any

protective coveralls, nor did they change clothes after shooting. Additionally, the ventilation system on site was found to be inadequate for removing lead particulate from the air and it was recommended that it be improved to meet National Institute for Safety and Health (NIOSH) standards. The authors noted that even limited time spent shooting by recreational users can result in significant lead exposure that may produce adverse effects on health.

In 2012, NIOSH performed a follow-up study to determine whether a newly installed ventilation system in an indoor firing range was effective in reducing shooters' exposure to lead.<sup>11</sup> The new system met the NIOSH-recommended minimum airflow of 50 feet per minute along the firing line and a recommended downrange minimum airflow of at least 30 feet per minute.<sup>16</sup> They noted that the new ventilation system resulted in a substantial (twentyfold) reduction in the average air lead exposures for shooters.<sup>11</sup> The average air lead concentration for shooters was now 5.0  $\mu\text{g}/\text{m}^3$ , compared to 102  $\mu\text{g}/\text{m}^3$  in the previous 2009 evaluation.

Shannon reported a case of four competitive marksmen (all adolescent girls) at the same indoor firing range who showed lead levels of 18 to 28  $\mu\text{g}/\text{dL}$  even though health and safety measures recommended by the range, including hand washing and clothing changes, had reportedly been followed.<sup>17</sup>

A lead exposure study in Alaska found that at four of the five indoor ranges investigated, blood lead levels were elevated among students (7 – 19 years of age) on shooting teams.<sup>8</sup> Mean blood lead levels ranged from 7.6  $\mu\text{g}/\text{dL}$  to 24.3  $\mu\text{g}/\text{dL}$ . None of the four ranges had written protocols for maintenance, and three had inadequate ventilation systems (ventilation at the fourth was not assessed). The fifth range, where all shooters had blood lead levels  $\leq 5$   $\mu\text{g}/\text{dL}$ , had a modern, well-maintained ventilation system, followed a written lead maintenance protocol, and did not employ dry sweeping to clean the range.

Reporting on the blood lead levels of seven indoor marksmen in Germany, Oschsmann et al. found that all had elevated BLL values (median: 29  $\mu\text{g}/\text{dL}$ ; range: 24 – 45  $\mu\text{g}/\text{dL}$ )<sup>10</sup>. These exceeded levels typically found in the German general population (5  $\mu\text{g}/\text{dL}$ ). The authors noted that shooters sweeping the bullet trap were exposed to high levels of airborne lead dust (7.14  $\text{mg}/\text{m}^3$ ).

Both Demmeler et al. and Svensson et al. showed recreational shooters using powder charges containing lead had much higher blood lead levels than shooters using air propelled bullets.<sup>7,4</sup> Comparing the results to the German Human-Biomonitoring "safe" value (HBM) of 15  $\mu\text{g}/\text{dL}$ , Demmeler et al. noted that all airgun users were below the HBM, but 13% of .22 caliber users and 30% of heavy caliber shooters tested above these values. For competitive shooters, 73% had a BLL above the HBM.<sup>7</sup> Svensson et al. observed the same type of relationship. Marksmen who used powder charges had significantly increased blood lead levels during the indoor shooting season (before: median 10.6, range 3.2-17.6  $\mu\text{g}/\text{dL}$ ; after: 13.8; range 6.9-28.8  $\mu\text{g}/\text{dL}$ ;  $P = 0.0001$ ), while subjects who mainly used air guns displayed no significant increase (before: median 9.1, range 4.7-17.9  $\mu\text{g}/\text{dL}$ ; after: 8.4; range 2.0-22.2  $\mu\text{g}/\text{dL}$ ).<sup>4</sup> The authors concluded that there is a strong need for preventive action in the form of better ventilation systems and/or the use of lead-free ammunition.

Grandahl et al., in a recent study of Danish recreational shooters, found that almost 60% of the shooters from two ranges had a blood lead concentration above 10 µg/dL<sup>13</sup>. The median BLL was 11.6 µg/dL, ranging from <1.4 (below detection level) to 33.3 µg/dL. The authors concluded that a large proportion of Danish recreational indoor shooters had potentially harmful blood lead concentrations. Ventilation, amount of shooting, use of heavy calibre weapons, and length of time spent at the firing ranges were all independently associated with increased blood lead. Although the authors noted that inhalation of lead dust was a key risk factor for exposure, hand contamination from contact with lead-contaminated surfaces was also a significant source of exposure due to hand-to-mouth contact.

## TAKE-HOME LEAD

Take-home contamination occurs when lead dust is transferred from a shooter's skin, clothing, shoes, and other personal items to his/her vehicle and home.<sup>11</sup> No studies were found on take-home lead for recreational shooters. This does not, however, mean that it is not a potential issue. A recent NIOSH study detected lead on the hands, pants, and shoes of occupational shooters that transferred from the firing range into personal vehicles.<sup>11</sup> Lead in personal vehicles poses a potential exposure to other passengers, and has the potential to be tracked into the home where it can expose others, including children and pregnant women to lead. In a separate NIOSH indoor firing range investigation, workers were advised to send family members for BLL testing because of the potential for take home lead exposure.<sup>14</sup>

Take-home lead exposure has also been documented in construction work. Numerous studies have been published indicating that lead dust can be transported in workers' automobiles, and has the potential to stay on skin and clothing, resulting in take-home lead exposure.<sup>14;18-21</sup> In one such study, a surface sample from a child's car seat in one worker's automobile found a lead level of 108 µg/100 cm<sup>2</sup>, indicating that this route of exposure may be significant.<sup>21</sup>

## PREVENTIVE MEASURES

On the basis of the findings within the literature review, the points listed below are examples of actions that can be taken to reduce the risk of lead exposure and create a healthier shooting range environment. While clear evidence of the effectiveness of each measure is not available, they can be considered for use in locally tailored lead reduction initiatives at shooting ranges. The evaluation of lead exposures before and after the introduction of any of these measures is the best indicator of effectiveness.

- The most effective method for reducing lead exposure during shooting is to encourage the use of lead free ammunition.<sup>7;22;23</sup> The use of jacketed lead or non-lead bullets is shown to reduce lead levels at the firing range by as much as 80%.<sup>24</sup> It is important to realize that while some jacketed lead bullets do not produce airborne lead, impact with the bullet trap at the firing line may generate lead dust.<sup>24</sup>
- Ventilation systems for indoor firing ranges should be assessed by a knowledgeable person/consultant familiar with firing range design. The NIOSH recommended airflow along the

firing line is 50 – 75 feet per minute (0.9 - 1.25 metres per second) and at least 30 feet per minute (0.5 metres per second) downrange in order to minimize the fallout of lead emissions downrange of the firing line.<sup>16</sup>

- The supplied air should move smoothly and steadily across all shooting booths, carry the shooting emissions away from the shooters' breathing zones and directly down the range where it should be exhausted and subject to high-efficiency particulate air (HEPA) filtration before being discharged to the outdoors.<sup>24</sup>
- The ventilation system should be maintained so that it operates at designed capacity and should be assessed on a regular basis by a knowledgeable person to ensure air flow is maintained.<sup>10</sup>
- Shooters and volunteer workers involved in housekeeping or maintenance activities at the range should be aware of the adverse effects of lead on health, symptoms of lead toxicity and how to minimize exposure. The level of knowledge of the shooters and volunteer workers, as well as their willingness to implement preventive measures, is of the utmost importance when it comes to lead exposure at firing ranges.<sup>10;25</sup>
- If shooters and volunteer workers (especially children and women of child bearing age) believe they have had significant exposure to lead they should ask their health care provider about having a blood lead test.
- Volunteer firing ranges might consider having a trained health and safety volunteer who will initiate and supervise education of both shooters and other volunteer workers.<sup>10</sup>
- Eating, drinking or smoking inside the firing range should not be allowed.<sup>25</sup> Lead dust residue on the hands, arms and face may result in ingestion of lead through hand-to-mouth contact.<sup>10</sup>
- Children and adolescents should not be allowed to perform housekeeping or maintenance activities at the range.<sup>8</sup>
- Shooters and volunteer workers should be encouraged to wash up or shower (if available) immediately after shooting or performing housekeeping or maintenance activities.
- Posters can be prominently displayed to remind shooters and volunteer workers to wash their hands, and not to eat, drink or smoke inside the firing range.
- Good housekeeping practices should be instituted to remove lead from surfaces.<sup>26</sup> The following points should be noted:
  - Do not clean up using dry sweeping in the firing range - this will generate airborne lead dust. Instead, use wet wiping or mopping for non-porous surfaces and HEPA vacuuming for porous surfaces.<sup>24</sup>
  - Surfaces can be adequately cleaned with an all-purpose household detergent.<sup>27</sup>

- Do not place carpeting or rugs in rooms adjacent to the firing range. Carpets and rugs are hard to clean and could accumulate lead dust, increasing the opportunity for contaminating shoes and clothing.<sup>24</sup>
- As a measure of cleaning efficiency, lead testing on surfaces can be done using surface wipe samples. Although there are no established limits for lead concentrations on surfaces in ranges, all surfaces should be as free as is practical of accumulations of lead.
- Ensure that adequate personal protective equipment, including skin protection, eye protection and NIOSH approved respirators suitable for protection against lead dust are used by volunteers involved in maintenance and cleaning of lead-contaminated surfaces and areas.<sup>24</sup>
- Respirators should be worn with the sealing surface positioned directly against the skin in order to ensure a good face-to-respirator seal. The areas of the face where the respirator seals with the skin must be clean-shaven. Stubble prevents the respirator from forming a good seal with the face.
- Cleaning the bullet trap can be a source of high lead exposure, therefore airborne lead dust should be minimized by repeatedly misting the sand and debris with water.<sup>10</sup>
- Clothes and shoes should be changed at the range after shooting, housekeeping or maintenance activities, and placed in an airtight bag for transport to prevent lead from being tracked into cars and homes.
  - Disposable shoe coverings can be used while shooting or performing housekeeping or maintenance activities, then discarded when leaving the range.
  - Clothes worn at the firing range should be stored separately from other clothes and be washed separately from other household laundry.<sup>24</sup>
- Recycling lead by smelting or casting of bullets should not be done onsite unless performed in a workshop that is properly designed to control lead exposure. Additionally, all persons who perform these tasks should be trained and knowledgeable about how to protect themselves from lead exposure.<sup>12</sup>

## CONCLUSION

Recreational shooters and volunteer workers at indoor firing ranges and their families can be exposed to hazardous amounts of airborne lead if proper controls are not in place. Recommendations for controlling exposures to lead at indoor firing ranges include use of jacketed or lead free bullets, use of a separate ventilation system for firing lanes, proper hygiene practices, proper range maintenance and use of wet mopping or HEPA vacuuming instead of dry sweeping to remove dust and debris. Use of jacketed or lead free bullets should be the first consideration before implementing engineering and administrative measures.

## PUBLIC HEALTH PRACTICE IMPLICATIONS

Because the Ministry of Labour health and safety regulations may not apply to volunteer-run ranges, health units may wish to identify indoor volunteer-run ranges in their jurisdictions and conduct a lead-risk assessment to determine whether the health of shooters and volunteer workers or their families is likely to be affected due to lead exposure. In an effort to ensure the safety of the public, ranges with inadequate preventative measures in place can be offered advice on how to reduce the risk of lead exposure.

## Appendix A

National Toxicology Program's (NTP) 2012 monograph on the health effects of low-level lead exposure concluded the following about the evidence regarding health effects of lead.

System affected	Population	NTP conclusion	Principal health effects	Blood lead evidence (µg/dL)
Neurological	Adult	Sufficient	Increased incidence of essential tremor	Yes, < 10
		Limited	Psychiatric effects, decreased hearing, decreased cognitive function, increased incidence of amyotrophic lateral sclerosis	Yes, < 10
		Limited	Increased incidence of essential tremor	Yes, < 5
	Children	Sufficient	Decreased academic achievement, intelligence quotient, and specific cognitive measures; increased incidence of attention-related behaviours and problem behaviours	Yes, < 5
		Sufficient	decreased hearing	Yes, < 10
Immune	Adult	Inadequate	–	Unclear
	Children	Limited	Increased hypersensitivity/allergy by skin prick test to allergens and increased immunoglobulin* (not a health outcome)	Yes, < 10
		Inadequate	Asthma, eczema	Unclear
Cardiovascular	Adult	Sufficient	Increased blood pressure and increased risk of hypertension	Yes, < 10
		Limited	Increased cardiovascular-related mortality and electrocardiography abnormalities	Yes, < 10
	Children	Inadequate	–	Unclear
Renal	Adults	Sufficient	Decreased glomerular filtration rate	Yes, < 5
	Children ≥12 years old	Inadequate	–	Unclear
	Children <12 years of age	Limited	Decreased glomerular filtration rate	Yes, < 5
Reproductive and development	Adult	Sufficient	Women: reduced fetal growth	Yes, < 5
			Men: adverse changes in sperm parameters and increased time to pregnancy	Yes, ≥ 15–20
		Limited	Women: increase in spontaneous abortion and preterm birth	Yes, < 10
			Men: decreased fertility	Yes, ≥ 10
			Men: spontaneous abortion in partner	Yes, ≥ 31
	Inadequate	Women and men: stillbirth, endocrine effects, birth defects	Unclear	
	Children	Sufficient	Delayed puberty, reduced postnatal growth	Yes, < 10
Limited		Delayed puberty	Yes <5	

## APPENDIX B

### Search Methods

Comprehensive literature searches were executed in MEDLINE, Embase, Scopus, Environment Complete, and Compendex. A web search for grey literature was also executed. Search terms related to lead (lead, Pb, PbB, BLL), firearms (shoot\*, shot\*, gun\*, handgun\*, firearm\*, "firing range\*", rifle\*, pistol\*, ammunition, bullet\*, marksman, marksmen), and indoor ranges (indoor\*, building\*, construct\*, design\*, ventilat\*, "air filt\*", "air sampl\*") were combined in the search queries. Limits on the language of publication (English) and date of publication (1990 - 2014) were applied to the searches. Searches were executed on February 6, 2014.

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**Public Health Ontario**

480 University Avenue, Suite 300  
Toronto, Ontario  
M5G 1V2

647.260.7100

[communications@oahpp.ca](mailto:communications@oahpp.ca)

[www.publichealthontario.ca](http://www.publichealthontario.ca)

