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Elevated Blood Lead Levels Related to the Use of Firearms

To the Editor:

Lead is well known to cause toxicity to multiple organs, even at low levels of exposure.[1] Public health workplace and environmental regulations and practices have resulted in substantial reductions in lead exposure in the United States[2,3]; however, lead remains a serious and preventable hazard, with lead ammunition and the use of firearms an important preventable but underappreciated source of lead exposure.[4] Elevated blood lead levels have been documented in firing range workers, military and enforcement personnel,[5] and increasingly in recreational firearm users.[6] Although lead-free ammunition is available, the most common source of nonoccupationally elevated blood lead levels reported in the United States is now the use and maintenance of firearms.[7] Despite the well-documented risks of leaded ammunition, the risks of lead exposure from firearm use are not well appreciated among health care providers and the general public, hindering recognition and preventive measures.

The potential for lead exposure and toxicity from the use of firearms is of particular concern in the United States, given that approximately 15% of the US adult population are estimated to regularly participate in target shooting,[8] and many others hunt wildlife. Lead-based ammunition is also an important source of lead in the environment, leading to toxicity in wildlife as well as humans.[9,10]

Summarized in Table 1 are six cases of elevated blood lead levels in our clinic related to firearm use from 2011 until 2014, with associated lead exposure settings, blood lead levels, and symptoms reported.

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CONNECTICUT ADULT LEAD SURVEILLANCE DATA

The Connecticut (CT) Department of Public Health, as part of the Centers for Disease Control and Prevention's state-based Adult Blood Lead Epidemiology and Surveillance (ABLES) program, collects data on adult blood lead levels from laboratories and providers.[7] As shown in the Fig. 1, the total number of elevated blood lead levels (>20 μg/dL) reported in CT rose from 64 in 2003 to 113 cases in 2013, and the number of adult cases associated with firing ranges rose from 0 in 2003 to 26 in 2013. The percentage of elevated blood lead levels related to firing ranges rose from 0% in 2003 to 23% in 2013 (Fig. 1).

DISCUSSION

This case series and the related lead surveillance data demonstrate substantially elevated blood lead levels among individuals involved in recreational and occupational firearm use in CT. These findings demonstrate that lead exposure from the use of firearms, which constitutes a serious, known and preventable occupational and environmental hazard, persists and may even be increasing. The findings, consistent with nationwide ABLES surveillance data, highlight the inadequacy of the current regulatory efforts to prevent lead exposure associated with firearm use, as well as the lack of awareness of this important hazard among clinical providers and the general population. In one of the cases, an elevated blood level in a firing range coworker prompted lead blood testing. In all other cases, lead exposure related to firearm use was not suspected and was identified only after an elevated blood lead level in the patient or a family member triggered further evaluation, most importantly questions regarding the patient's occupation and hobbies.

The degree of elevation in blood lead levels (35 μg/dL to 52 μg/dL, mean 43.3 μg/dL) is also notable. It is unclear whether these levels represent acute or more chronic exposures. Although acute lead toxicity is not typically seen at these levels, chronic lead levels less than 20 μg/dL have been associated with increased risk of neurologic, cardiovascular, renal, and reproductive adverse effects, and lower blood lead levels (<5 μg/dL to 10 μg/dL) of concern in children.[11,12]

Our findings also underscore the importance of lead surveillance and the underappreciated risk of firearm-related lead exposure in young children, who are at much greater risk of chronic neurologic toxicity.[11,13] Two of the cases came to medical attention because of mandatory lead surveillance of a young child (in these cases, it was the son or the grandchild). Pediatric lead surveillance, motivated by the historic use of leaded paint, is mandatory in CT but not nationwide. Given how widespread gun ownership is in the United States, firearm use among household members may be an important and unrecognized source of childhood lead exposure.

These cases also highlight the many different sources of lead exposure related to the use and maintenance of firearms, including inhalation and/or ingestion of lead dust and/or fumes from spent bullets, contact with contaminated surfaces and clothing, bullet making, and cleaning firearms. Lead contamination of surfaces in indoor firing ranges, as well as upholstery and other surfaces in the homes and vehicles of firearms workers, has been reported.[11] Lead can thus be brought home unknowingly to family members or to other workplaces, as likely occurred in three of the cases here.

Although indoor firing ranges have been the primary concern, elevated blood lead levels have also been reported from the use of outdoor ranges, as likely occurred[14] with case 4. Published data on the risks of lead exposure from tasks such as gun cleaning and bullet making, especially in the home setting, are limited. Given our limited ability to perform lead sampling, it is difficult to be certain which gun-related activities contributed to each case's elevated blood lead level; however, thorough evaluation of the six cases, including a careful exposure, and workplace and/or home site visits where possible revealed no other sources of lead exposure.

The extent of lead exposure related to firearm use is unclear because lead surveillance is not mandatory, and an elevated blood lead level does not mandate lead surveillance in coworkers or family members; however, available surveillance data suggest that cases of elevated lead levels associated with firearm use are underreported and may be increasing. National ABLES surveillance data from 2002 to 2012 show an increase in the percentage and total number of elevated blood lead levels related to firearm over this time period, from 22.9% ($n = 572$) to 38.0% ($n = 1156$) of all nonoccupational

TABLE 1. Lead Exposure Settings and Associated Blood Lead Levels and Symptoms Among Cases

	Lead Exposure Setting	Blood Lead Level*	Symptoms
Case 1	A 70-year-old male self-employed firearms instructor, who instructed firearms classes and shot recreationally in an indoor firing range. He routinely cleaned firearms on the kitchen table. He was referred to our clinic by his neurologist for unsteady gait.	47 μg/dL	Unsteady gait
Case 2	A 28-year-old male part-time maintenance worker at indoor shooting range, whose elevated blood level was discovered after his 1-year-old son was found to have a markedly elevated blood lead level (33 μg/dL) on routine pediatric lead screening. No source of lead, such as lead paint, was identified at the child's home. The maintenance worker's job tasks included sweeping used ammunition and picking up residual bullet casings.	45 μg/dL	Abdominal pain, fatigue
Case 3	A 59-year-old male firearm salesman at an indoor shooting range, who assisted with pistol permit classes and retail sales. Elevated lead levels in coworkers prompted him to check his own blood lead level, after which he self-referred to our clinic.	52 μg/dL	Asymptomatic
Case 4	A 66-year-old male US veteran, who was referred to our clinic by his neurologist for symptoms of intermittent paresthesias in his left foot, with decreased lower extremity motor nerve conduction velocity on diagnostic testing and an elevated lead level. He worked as a firearms instructor for 8–18 yr olds at an outdoor shooting range.	37 μg/dL	Intermittent parasthesias in left foot
Case 5	A 36-year-old male, who was referred by his physician for further evaluation of an elevated lead level. He owned a firearm shop that was adjacent to an indoor firing range. Countertops, surfaces, and floors in his shop were contaminated with lead dust tracked in from customers after using the range.	44 μg/dL	Fatigue
Case 6	A 62-year-old US veteran grandfather, who was noted to have an elevated blood level after his 2-year-old granddaughter's elevated blood lead level was detected on routine pediatric screening, similar to case 2. No source of lead was identified in the child's home. As a competitive shooter, he practiced in an indoor range several times a week, wearing the same clothes home in the pickup truck he drove his granddaughter around in. He also melted lead blocks to cast bullets in the back of his truck and sanded the bullet edges in his basement.	35 μg/dL	Asymptomatic

*Blood lead levels at least 10 μg/dL in adults are considered elevated by the National Institute of Occupational Safety and Health, and the Centers for Disease Control and Prevention. Blood lead levels 5 μg/dL or more in children are considered elevated by the Centers for Disease Control and Prevention.

elevated blood levels. Firearm use has become the most commonly reported non-occupational source of lead exposure in the United States, more common than lead paint.[11] The percentage of occupational elevated blood lead levels related to shooting ranges also increased, from 0.4% ($n = 56$) to 1.9% ($n = 357$).[11] A recent report found that almost half of the firing range employees (22/46) in the State of Washington had elevated blood lead levels.[11] Another recent investigation found elevated blood lead levels in 6 of 6 firing range workers (100%), none of whom had undergone medical surveillance, along with widespread lead contamination of surfaces, clothing, and hands.[11] Yet surveillance of firearm workers or recreational shooters is not mandated nor routinely performed.

The CT surveillance data presented here are consistent with these published reports. A review of our clinic database also found an increase in the number of elevated blood lead levels related to firearm use, with six patients in the last 4 years and only one patient in the prior 15 years. The

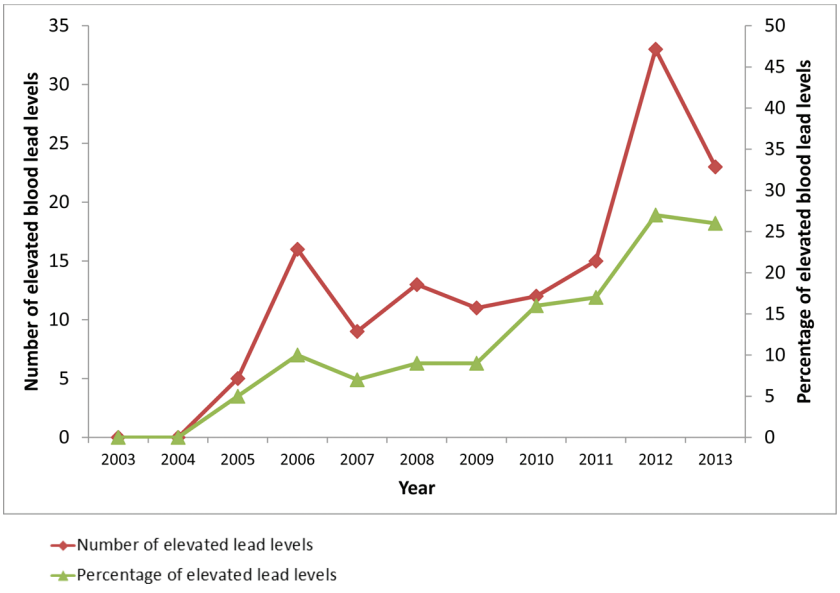

FIGURE 1. Number of elevated blood lead levels (>20 mg/dL) related to firing range exposures and the percentage of all elevated blood lead levels in adults related to firing range exposures (2003–2013).

ABLES data likely represent a low estimate of the problem of gun-related lead. For the cases presented, testing of coworkers or family members was recommended where indicated but was difficult to implement.

Despite the increasing number of reported cases of lead exposure related to firearm use, clinician and general public awareness of this important hazard remains low,[15,16] and there has been little attention to primary prevention, namely the use of lead-free bullets. The principal concern of adult and pediatric medical organizations regarding firearms has focused on safety. The American Academy of Pediatrics recommends addressing firearm safety with parents, and the American College of Physicians advocates for counseling patients on the risk of firearms, especially when children are present[17,18]; however, neither professional organization mentions the risk of lead exposure.

This article demonstrates the challenges in preventing lead exposure using secondary and tertiary preventive efforts, including engineering controls and surveillance, respectively. Lead-free bullets are available and would greatly reduce human and environmental lead exposure.[11] California has banned the use of lead for hunting ammunition by 2019,[19] and the United States military is transitioning to lead-free ammunition[20]; however, leaded bullets remain the primary consumer ammunition in the United States.

Until lead-free bullets become widespread, clinicians should inquire about firearm use and employment as a source of lead exposure in adults and children and should have a low threshold for obtaining a blood lead level. An elevated blood lead level should prompt further investigation of potential sources of exposure in the home, at work, and related to leisure activities, and also prompt testing of family members, especially young children, and coworkers if also at risk.

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REFERENCES

1. Marsden PA. Increased body lead burden—cause or consequence of chronic renal insufficiency? *N Engl J Med*. 2003;348:345–347.
2. Lin JL, Lin-Tan DT, Hsu KH, Yu CC. Environmental lead exposure and progression of chronic renal diseases in patients without diabetes. *N Engl J Med*. 2003;348:277–286.
3. United States Department of Labor: Occupational Safety and Health Administration. *Lead in Construction*. OSHA 3142-12R;2004.
4. Centers for Disease Control and Prevention. Adult Blood Lead Epidemiology and Surveillance—United States, 2008–2009. *MMWR Morbidity Mortality Weekly Rep*. 2011;60:841–845.
5. Lofstedt H, Selden A, Storeus L, Bodin L. Blood lead in Swedish police officers. *Am J Ind Med*. 1999;35:519–522.
6. Demmeler M, Nowak D, Schierl R. High blood lead levels in recreational indoor-shooters. *Int Arch Occup Environ Health*. 2009;82:539–542.
7. Centers for Disease Control and Prevention. Adult Blood Lead Epidemiology and Surveillance (ABLES): ABLES program description. 2013. Available at: http://www.cdc.gov/niosh/topics/ABLES/description.html. Accessed July 1, 2014.
8. Responsive Management (Conducted for the National Shooting Sports Foundation). Excerpts from Sport Shooting Participation in the United States in 2009: Related to the Subject of Modern Sporting Rifles. 2010;i–ii.
9. Bellinger DC, Burger J, Cade TJ, et al. Health risks from lead-based ammunition in the environment. *Environ Health Perspect*. 2013;121:A178–A179.
10. Gelberg KH, Depersis R. Lead exposure among target shooters. *Arch Environ Occup Health*. 2009;64:115–120.
11. Centers for Disease Control and Prevention. Indoor firing ranges and elevated blood lead levels—United States, 2002–2013. *MMWR Morbidity Mortality Weekly Rep*. 2014;63:347–351.
12. National Toxicology Program. NTP monograph: health effects of low-level lead. *NTP Monogr*. 2012;xix–xx.
13. Landrigan PJ, McKinney AS, Hopkins LC, Rhodes WW, Jr, Price WA, Cox DH. Chronic lead absorption. Result of poor ventilation in an indoor pistol range. *JAMA*. 1975;234:394–397.
14. National Institute for Occupational Safety and Health: Workplace Solutions. Reducing Exposure to Lead and Noise at Outdoor Firing Ranges. DHHS (NIOSH) Publication No. 2013-104, November 2012.
15. Azaroff LS, Levenstein C, Wegman DH. Occupational injury and illness surveillance: conceptual filters explain underreporting. *Am J Pub Health*. 2002;92:1421–1429.
16. Rosenman KD, Kalush A, Reilly MJ, Gardiner JC, Reeves M, Luo Z. How much work-related injury and illness is missed by the current national surveillance system? *J Occup Environ Med*. 2006;48:357–365.
17. American Academy of Pediatrics. American Academy of Pediatrics Gun Violence Policy Recommendations. January 2013. Available at: https://www.aap.org/en-us/advocacy-and-policy/federal-advocacy/Documents/AAPGunViolencePreventionPolicyRecommendations_Jan2013.pdf. Accessed July 1, 2014.
18. Butkus R, Doherty R, Downey H. Reducing firearm-related injuries and deaths in the United States: executive summary of a policy position paper from the American College of Physicians. *Ann Intern Med*. 2014;160:858–860.
19. California Department of Fish and Wildlife. Nonlead ammunition in California. Available at: https://www.wildlife.ca.gov/Hunting/Nonlead-Ammunition. Accessed July 1, 2014.
20. Lopez CT. "Green bullet" as effective as M855 round—consistently. United States Army; 2011. Available at http://www.army.mil/article/56157/. Accessed July 1, 2014.

