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Systematic Review

Occupational Lead Exposure and Safety Measures at Shooting Ranges: a Systematic Review

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Abstract

Background: Individuals at shooting ranges are exposed to high amount of lead fumes either indoor or outdoor. The shooters sprayed lead dust into the air upon discharge of the cartridge at arm's length distance. Most of the previous studies conducted at shooting ranges focused on blood lead levels (BLLs) of exposed people and there are limited studies on the risk associated with the shooting of firearms. This study aimed to review previous studies on the hazards associated with the discharge of firearms, and safety measures at shooting ranges. **Methods:** A systematic review was conducted to explore the available evidence. The databases were searched using the keywords "indoor shooting ranges", "outdoor shooting ranges", "firearms shooting", "lead poisoning hazard", "blood lead biomarkers", "permissible exposure limit", and "safety practice on lead". **Results:** The designated BLL for case definition in lead poisoning was between 0.1µg/dL - 0.49µg/dL. It was estimated that at Permissible Exposure Limit (PEL). PEL of 0.5µg/m^3, 95 percent of range users who are exposed to lead poisoning regularly can have BLL of <5µg/dL during 20 years of working life, while at 2.1µg/m^3, 95 percent of the workers can have BLL of<10µg/dL during their working life. **Conclusion:** To protect firearm handlers and shooting range workers, policy on preventive measures should be implemented at shooting ranges by policymakers. Compliance with preventive measures is encouraged to avoid the high cost of rehabilitation lead poisoning.

Keywords: Shooting Ranges; Lead Poisoning Hazard; Firearm Handlers; Safety Measures

Introduction

Regular inspection of indoor or outdoor shooting ranges to determine the exposure to lead pollutants in firearms handlers and workers is often partly controlled for years. [1] Given that shooting ranges were meant to train officers and re-qualify them to prove their proficiency in firearm handling; it is required to review lead poisoning threat associated with the shooting of firearms and the safety measures. [2]

The acute effect of lead poisoning and subsequent death arising from over-exposure to lead pollutants was emphasized by a German physician (Ellenberg, 1440 – 1499) in the fifteen century. [3]In the 16th century during pre-industrial era, Ellenberg recognized the effect of lead poisoning among slaves and manual workers though it was not considered by medicine. [4] A theory was developed by Paracelsus who lived (1493 – 1541), and it states that *"only the*

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dose permits something not to be poisonous" and this idea marked the development of toxicology which was widely and bitterly criticized by scientists worldwide during the period. [5]

Lead is a metallic element represented with the symbol (Pb), very soft in nature with a blue-gray color in appearance, and takes its name from the Latin word Plumbum, meaning lead. [6] The lead properties like low melting point, easy workability, ability to hold pigments well and form carbon, a high degree of corrosion resistant, very easy to recycle and low cost made it commercially attractive. [7]

The low melting temperature of lead made it highly malleable in the mass production of the pistols, rifles, cannons, and ammunition. [8] In the 1990s, ammunition was copper jacketed and it was thought that lead exposure through handling of ammunition could be eliminated; however, upon discharge of cartridge, the lead dust sprayed into the air at arm's length from shooter is of significant hazard. [9]

Bullet projectiles are mostly made from lead, and similarly, a large amount of lead is present in the primer which contains approximately 35% of lead peroxide and styphnate (also antimony and barium compound) that provides the propulsion for the projectile when ignited in a firearm barrel. [10]

The primary or main source of lead poisoning at shooting ranges results from lead used in the bullet primer, and the fine dust generated from this primer blows back onto the shooters, where it is inhaled, ingested or adhered to clothing and dermal absorption occur. [11]

A secondary exposure source is the fragmentation of bullets as they leave the end of the barrel, there is a disintegration of the lead bullet into a small fine fragment that passes through the gun as a result of misalignment of the gun barrel. [12] Subsequently, lead dust escaped in the form of particles along with air fumes from lead primer as bullets are ejected at high pressure of between 18,000 to 20,000 psi and 124 to 128mpa from gun barrel, and this occurs at right angular direction of the shooters. [12] These fine lead particulates from the primer are inhaled by the gun shooters and this constitutes the proximal exposure pathway. [13]

The coarse and fine particles of the lead dust from bullet fragments and primer also attached to the surfaces of the shooters clothing and hands, and this can be ingested if no proper safety measure is taking, this serve as another exposure pathway. [14] Furthermore, at the outdoor shooting range, shooters are exposed to lead particles already accumulated in the soil during the process of changing targets. [15] There is a chance that shooters can bring these lead particles back home thereby exposing their family members to lead poisoning hazard. [16]

The means of assessing the toxicity and risk of lead poisoning is to determine the blood lead level (BLL) of an individual and is the most widely used biomarker for human. [17] The reliable specimen for determining BLL is the venous blood since it is uncontaminated and preferred, and is considered confirmed. [18]

Studies on BLL threshold had indicated there is "no safe" amount of lead in the human system, no matter how small, and that no amount is too small to cause biological reaction. [19] In December 2015, National Institute of Occupational Safety and Health [NIOSH] in collaboration with other organizations designated BLL between 0.1µg/dL to 0.49µg/dL as the case definition level that call for concern in adults if the whole blood collected for testing is a venous blood sample. [20]

The outcomes of most of the studies conducted at shooting ranges in Nigeria were largely on BLLs of the firearms handlers and range workers. Studies related to the risk associated with the shooting of the firearms, and the safety approaches are dearth in literature. Therefore, the present study aimed to review and analyze studies on lead poisoning hazard

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associated with the discharge of firearms, and the safety practice at shooting ranges.

This study explored how firearms handlers and workers were exposed to lead poisoning hazard upon shooting of the firearms and taking safety measures. The article was not intended to restrain shooting or reloading activities of the firearms handlers and workers in the shooting ranges, but rather to create awareness about the possibility of the exposure to lead poisoning hazard and the safety measures. This systematic review fills a knowledge gap as it focused on lead poisoning hazard associated with the shooting of guns and the preventive approach.

Methods

Study design

A systematic review was used to address the research questions. The articles and publications that were systematically reviewed were studies on hazard associated with discharge of firearms, and safety measures at the shooting ranges from 1999 to 2018. The databases searched included Google scholar; Willey online library; PubMed; EBISCO; Iran Scopus; Directory of Open Access Journals; JSTOR; ScienceDirect; SID; Medex; Web of Science; and Cochrane Library. The keywords used for the search included "indoor shooting ranges", "outdoor shooting ranges", "firearms shooting", "lead poisoning hazard", "blood lead biomarkers", "permissible exposure limit", and "safety practice on lead". The articles were assessed and evaluated based on the standard of the studies. The evidences gathered from relevant articles was summarized and synthesized based on the guidelines used to conduct a systematic review.

Inclusion criteria

The included studies analyzed the cause-effect relationship of lead poisoning hazard associated with the shooting of guns at ranges and the safety measures. Also, they were authentic studies published in English language by recognized learned journals from 1999 to 2018.

Exclusion criteria

Articles on BLLs without considering lead hazard and safety interventions were excluded. Also, articles published before 1999 and after 2018, and those not published in learned journals were excluded. Furthermore, articles presented in seminars, commentary, editorials, perspective, report and review articles were excluded. Thirty-four articles were investigated based on the aim of the study. Figure 1 represents the flow diagram of how studies were selected for this study.

Data collection and analysis

The data were collected from the relevant studies evaluated and analyzed for this study. The literature search, evaluation and analysis were carried out by the author within four months. The results of the analysis were based on the evidence gathered from the relevant quality studies reviewed for this study.

Results

The studies investigated in this systematic review were largely conducted in the developed countries like United States of America, Latin and North America, United Kingdom, and Asia. Few studies conducted in developing countries of Sub-Saharan region were also investigated. The total number of articles included in this study was (N=34). Five articles (14.71%) were on indoor shooting ranges, n=11 (32.35%) on outdoor shooting ranges, n=2 (5.88%) on safety measures, n=10 (29.41) on military, police, and intelligence agency, while n=6 (17.65%) articles were on shooting range environment.

The summary of the percentage of the studies reviewed in term of the methodology used by the authors includes Cross-sectional n=12 (35.30%), descriptive-analytical n=4 (11.77%), descriptive n=3 (8.82%), correlation studies n=10 (29.41%), cohort studies n=3 (8.82%), and case control studies n=2 (5.88%). The designated reference BLL for case

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definition in adult workers expose to occupational lead poisoning in the U.S. is between (0.1µg/dL - 0.49µg/dL) [20] but, "no safe" level, considering the health hazard associated with lead poisoning in human being.

Firearm handlers, range workers, instructors, and trainees are exposed to lead pollutant with firing of the primer, and the Permissible Exposure Limit (PEL) that requires action at the shooting range is 30µg/m, [3] though the outdoor shooting range is somewhat well-ventilated compared to the indoor, they both contain more lead dust compared to other environments without lead pollutants. [21] Based on the permissible exposure limit at the range, it was estimated that at PEL of 0.5µg/m, [3] 95 percent of the people exposed to lead poisoning at ranges can have BLL of <5µg/dL during 20 years of working life, while at 2.1µg/m^3, 95 percent of the workers can have BLL of <10µg/dL during their working life. [21]

Table 1 shows case definition range for BLL of workers who are occupationally exposed to lead poisoning and the required safety measures. There is need to check the BLL of affected person ranging from 0.1µg/dL to 0.49µg/dL monthly for 3 months to ensure 0.00µg/dL is achieved. The BLL ≥ 5.0µg/dL indicates lead toxicity and should be checked monthly until the value of 0.00µg/dL- 0.01µg/dL is achieved.

Discussion

This study was carried out with the main objective of establishing the cause-effect relationship that exists between lead poisoning hazard and the shooting of firearms at ranges, and the safety measure approaches. At the shooting ranges, the most significant source of airborne lead is caused by the hot flames of the burning gun powder acting on the exposed lead base of a primer.

The PEL that requires action at shooting ranges is 30µg/m^3, but the fact remains that there is "no safe" level of lead poisoning in the body; since at low doses, lead produce a lethal effect in the body[21]. The PEL of 0.5µg/m^3 to 2.1µg/m^3 was recommended by the Occupational Lead Poisoning Prevention Program (OLPP) but not safe considering the case definition of lead poisoning and health implication in the human body.

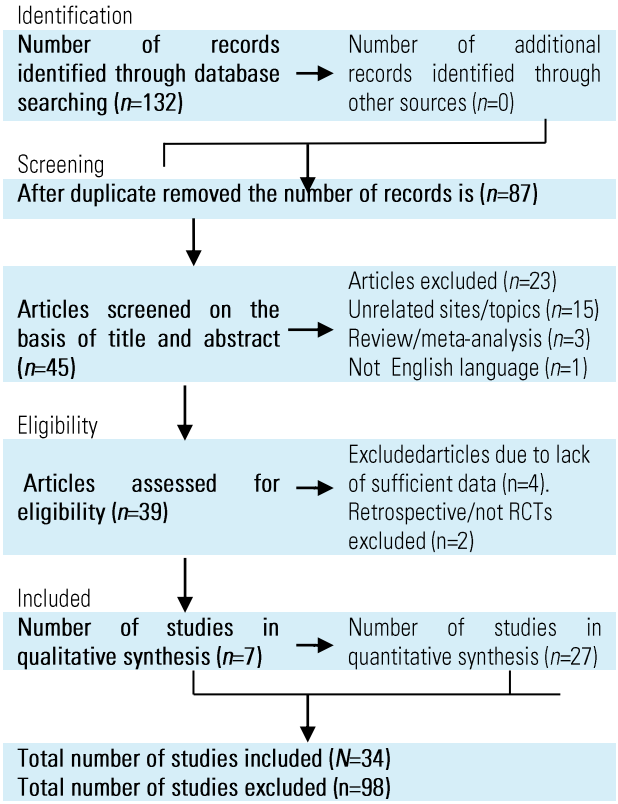

Figure 1. Flowchart of study selection for the systematic review

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Table 1. The BLL of occupationally exposed workers and required safety measures, January 2020

BLL value (µg/dL)	Safety decision	Health and safety measures
Case definition range		
BLL (0.1µg/dL - 0.49µg/dL)	Case definition for BLL though **"no safe value"**	Check BLL monthly for 3 months to ensure 0.00µg/dL level is achieved.
BLL (0.5µg/dL – 1.49µg/dL)	-Remove pregnant women from lead exposure or women in reproductive age. -Evaluate workplace lead exposure, available controls and safety measures.	Check BLL monthly for 3 months, then every 3 months until the value of 0.00µg/dL - 0.01µg/dL level is achieved.
Range that call for caution		
BLL (1.5µg/dL – 1.99µg/dL)	-Implement workplace changes to reduce exposure to lead. -Inform workers of the health implication of high BLL. -Evaluate sources of excessive exposure to lead, and identify ineffective work safety measures.	Check BLL monthly and ensure value of 0.00µg/dL- 0.01µg/dL is achieved
Range dangerous to health		
BLL (2.0µg/dL – 2.49µg/dL)	-Is mandatory to inform worker of the health implication of BLL. -Remove worker from lead pollutants and apply medical treatment until BLL returns to acceptable level. -Enhance safety measures to reduce exposure to lead using administrative and engineering controls to ensure safe practices.	Check BLL monthly until the value of 0.00µg/dL- 0.01µg/dL is achieved
Range that signify lead toxicity		
BLL ≥ 5.0µg/dL	-inform affected workers about their current BLL level. -Remove worker from lead exposure and commence medical treatment to return the BLL to acceptable level. -Notify medical director. -Identify sources of lead exposure at workplace and implement corrective actions to reduce or stop the exposure. -Control measures at workplace must be implemented to reduce exposure.	Check the BLL monthly until the value of 0.00µg/dL- 0.01µg/dL is achieved

Note: Table 1. Designed from the reviewed literature of ABLES/CDC/NIOSH, 2015, µg/dL = microgram per deciliter.

Wang et al. [22]conducted a study and found that continuous exposure to lead for 8 hours daily shows increase in PEL value, exceeding the estimated lead value in the ranges. It should be emphasized that the PEL value recommended by OLPP as action levels are not the only paths in controlling lead poisoning at shooting ranges but compliance with safety measures.

The implication of exposure to lead dust in the shooting ranges is that it may results into accumulation of the toxic lead metal in the human body. [23] Lead is one of the few substances not eliminated easily through the kidney, liver, or other methods of waste removals in human body, it damages red blood cells and causes nerve and cells degeneration in the brain leading to neurological defects and deaths. [24] Firearm handlers, range workers, civilian instructors, and frequent firearms shooters should realize that working in ranges, whether indoor or outdoor, or handling fired cases, requires precaution and encouragement of range officers to set a safety paradigm.

Lead in the soil is highly bioavailable; the half-life of lead in the soil at shooting ranges has been estimated at approximately 700 years. [25] Hence, if lead-contaminated soil at firing ranges is not remediated following closure, it could result into lead exposures for hundreds of years. [26] Exposure to lead is dangerous, even if no symptoms appears, workers are at increased risk of accumulating lead metal into their body system especially in a lead-contaminated shooting ranges due to lack of knowledge of safety

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practices. [26] According to Klein, [27] a lot of lead poisoning cases at firing ranges were as a result of lack of mopping up, not wiping the surfaces properly, not changing cloth, lack of hand washing, and no adequate ventilation, which is a big issue in indoor shooting ranges.

In the shooting ranges, lead-base ammunition fired by the officers will unknowingly spread lead vapors and dust into the air, and this is then inhaled, ingested and absorbed through the skin contact. [28] Although the risk of exposure to lead contaminants is greatly reduced at outdoor shooting ranges, but it is not completely eliminated as the firearm handlers may have lead particles attached to their shoes and clothing thereby serves as sources of contaminating their homes and putting children at risk of exposure to lead. [29] The implication of improper range management is that it could results into accumulation of lead poisoning in the human body leading to multiple organ damage. [30] Similarly, health problems can occur at a level as low as 0.1µg/dL of BLL according to Center for Disease Control and Prevention. [30]

Safety Measures at Shooting Ranges

The preventive strategies on lead poisoning was introduced in the mid-20th century, and it includes the use of personal protective equipment, lead dust wetting process, exhaust ventilation and use of chelating agent, which provided therapeutic tool against lead poisoning. [31] The ranges should be well ventilated and officers or trainees need to blow their nose after shooting or upon completion of the reloading session; since lead dust particles adhere to the body or clothes. [32] It is mandatory for firearms handler to wash their hands and faces before drinking, eating or smoking. [32] They must ensure their hair is washed thoroughly before bed as lead particles in the hair can be transferred into the pillow and ingested during sleep. [33]

Since lead poisoning symptoms tend to come on slowly and person with high BLL might not be able to recognize the onset of the condition until serious damage has occurred. [33] Therefore, the following safety rules and procedures are suggested at the shooting ranges either indoor or outdoor; moreover, safety codes should be boldly written and made visible. Eating, smoking, drinking, and use of cosmetic should be disallowed in shooting ranges. [34] Before leaving the shooting range daily, washing of hands and face with soap and water should be made compulsory, and plastic bags provided for the shooters to keep their contaminated clothes for laundry. [34]

Furthermore, shooters in the prone or kneeling position need to cover the ground with thick paper. Range workers involved in maintenance need to change cloth, take a shower, and wash their hair with shampoo daily to remove lead dust from their body before leaving the range. [34] Separate locker should be provided to separate clean cloth from the range clothes which are contaminated with lead particles. Dry sweeping of the shooting ranges should be prohibited; cleaning of the floor should be through vacuum with a unit designed for lead collection. Above all, a corrective measure is emphasized for early detection and prompt treatment of victim to prevent multiple end organ damage; since lead poisoning is treatable if detected in time. [34]

Conclusion

Studies have reported that firearm handlers were over-exposed to lead contaminants and even poisoned at shooting ranges. Despite the increase in cases of lead poisoning and overwhelming evidences of the dangers of lead, the harmful aspect of the shooting ranges are still neglected, either indoor or outdoor with its consequential effect on safety and health of the personnel shooting firearms.

Recommendations

It is recommended that shooting ranges use the Occupational Health and Safety Management Committee to develop an action plan that will focus

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on specific situation at shooting ranges. The action of the committee should be directed towards effectiveness in reducing or removing the risks of lead poisoning. Regular monitoring of shooting ranges should be performed by the occupational health inspectors. Firearm handlers and shooting range workers should set priorities, evaluate compliance with safety measures, and ensure that lead exposure is prevented.

Conflict of Interests

The author declared that there is no conflict of interest associated with this review.

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Authors Contribution

Tajudeen Olusegun Rasheed: designed, conceptualized, conducted the study and wrote the manuscript for publication.

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