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Technical Note

Children and guns: The detection of recent contact with firearms on children's hands by the PDT reagent

Karni L. Bar-Or [a], Joseph Almog [b,*]

[a] Herzliya Hebrew Gymnasium, Tel Aviv, Israel
[b] Casali Center for Applied Chemistry, Institute of Chemistry, The Hebrew University of Jerusalem, Jerusalem 91904, Israel

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ABSTRACT

Throughout the world, young children are worryingly found to be involved in both unintentional and intentional gun violence, rendering the forensic investigation of gun handling by children a highly important matter. The effectiveness of the PDT reaction for mapping iron traces on hands of children has been tested and compared to its application on adults. Counter-intuitively, children were found to produce considerably more intense PDT impressions than adults. A plausible explanation which is based on physiological differences between children and adolescents is suggested.

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1. Introduction

Brandon Holt, a 6-year old New Jersey boy, was pronounced dead, after being shot in the head by a 4-year old playmate, who retrieved a 22-caliber rifle within his house [1]. The incident follows another fatal shooting occurring several days earlier, involving another 4-year-old boy in Tennessee, firing a loaded pistol [2]. The shooting which took the life of 2-year-old Caroline Sparks in southern Kentucky has been ruled an accident. She was shot by her 5-year-old brother [3]. In South Carolina, a 7-year-old girl was killed at a birthday party after a 5-year-old boy accidentally fired a gun [4].

The Center for Disease Control and Prevention in the U.S. estimates that an average of 62 children of ages 14 and under are accidentally shot to death each year in the U.S. This number is lower than some other sources suggest. The number recorded by "Everytown for Gun Safety" is 100. It is reported that 73 percent of the deaths involved a shooter younger than fourteen [5]. One extreme example is a 2-year old baby, who shot his mother in a supermarket [6].

Young children are often introduced to guns at an early age. "In this part of the country, it's not uncommon for a 5-year-old to have a gun or for a parent to pass one down to their kid" comments Kentucky State Police Trooper Billy Gregory [3]. While U.S. federal law states that people younger than 18 cannot possess a handgun, there is no federal minimum age for possessing a long gun like a shotgun or a rifle. Most U.S. states do not set a minimum age for possessing a long gun [7].

In addition to unintentional fatal shootings, children and adolescents are often found to be involved in criminal violence involving guns – either individually or in armed youth gangs – throughout the world [8–12].

In Louisiana, an 8-year-old boy, intentionally shot and killed his elderly caregiver [13]. A 14-year old boy has been charged with manslaughter, in the shooting of a Toronto teenager [14]. In Jerusalem, a 14-year old boy took hold of his father's M-16 rifle and shot his father, his mother and his two sisters in their sleep. He then ran for help crying "someone is shooting in the house" [15]. Firearms are also used as the most common method for suicide, accounting for 736 deaths in the United States, according to a recent report [16,17]. The above reports and statistics render the forensic investigation of gun handling by children and adolescents a highly important matter.

In the investigation of crimes involving the use of firearms, the forensic scientist is often asked to demonstrate a link between a

* Corresponding author. Tel.: +972 2 6584558; fax: +972 2 6528250.
E-mail address: almog@mail.huji.ac.il (J. Almog).

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suspect and a weapon. One forensic method that approaches the crucial question "Who held the gun", known as the Trace Metal Detection Test (TMDT), or the Ferroprint™ test, relies on the development of invisible iron marks on the hand of the suspect [18–20]. During the handling of a weapon, minute amounts of iron are transferred from the metallic parts of the weapon to the skin of the "handler" *via* perspiration [21]. The Ferroprint™ technique involves spraying the subject's hand with a trace metal detection reagent: 3-(2-pyridyl)-5,6-diphenyl-1,2,4,-triazine (PDT). PDT is a highly sensitive reagent for Fe(II), immediately producing with it a magenta complex. Since the iron residues on the skin surface are readily oxidized to Fe(III), the Ferroprint™ reagent also contains a mild reducing agent (ascorbic acid) for converting the Fe(III) ions to Fe(II). The shape of the colored marks thus developed may indicate the type of firearm used or even the way it was held by the shooter.

PDT-based preparations are simple, inexpensive, and quite sensitive. Since 1980, the technique has been in operational use by crime-scene officers in the Israeli police, and became a part of the "field test concept" there. Spray cans containing PDT and ascorbic acid became commercially available under the trademarks Ferroprint™ and Ferrotrace™. Although the main application of the Ferroprint™ test is for visualizing handgun impressions on suspects' hands, this test may also be used for detecting imprints of burglary tools on suspects' skin surfaces [22,23].

In this study, we aimed to investigate the effectiveness of the PDT reaction in children – an age group which has not been studied before in spite of its connection to violence involving firearms. Particularly, we explored the influence of the age factor on the quality of the iron impressions.

2. Materials and methods

Two groups of volunteers participated in the study. The first group consisted of twenty one *adults*, males and females between the ages 30 and 50. Each volunteer was asked to grip an iron plier, which had served us in the past as a good model for handling of firearms. The gripping time duration was 1 min [21]. The volunteer's hand was then sprayed with PDT from a Ferroprint™ can, and immediately photographed with the use of a Canon Camera (equipped with a 35× Lens, 14.1 MegaPixels, SX30IS).

The second group consisted of seventy six *children* between the ages 6 and 15 that – in addition to be willing to volunteer to the experiment – also provided parental consent in writing (after a detailed explanation of the experiment's requirements was provided). In this group, contact was applied to both hands. Moisture levels were measured on both palms of each volunteer with a Corneometer® CM 825. This is an analytical device which is used experimentally and clinically for measuring the moisture on the upper 18–20 μm layer of the skin, mainly the stratum corneum. It measures the electric capacitance of the medium between its tracks. As the capacitance of the skin depends on its water content, a capacitance measurement can determine the amount of moisture on the skin surface. The influence of ground capacitance and other sweat components on the measured capacitance is insignificant, because the dielectric constant of water ($\varepsilon = 81$) differs greatly from that of most other substances ($\varepsilon < 7$; [24–26]). The readings are in arbitrary units and can vary between 0 and 120. This instrument was reported in the past for forensic studies involving sweat: Avissar et al. reported the correlation between palmar moisture and the amounts of iron which are transferred to the hand from holding a weapon [21]; Almog et al. studied the correlation between palmar moisture and fingerprint donorship [27]. Subsequent to the palmar moisture measurements, each volunteer was asked to grip an iron plier for 1 min. The hand was then sprayed with PDT, and immediately photographed.

All experiments were performed at room temperature, 25 ± 1.5 °C, under relative humidity of 70 ± 5%.

3. Results

The quality of the developed marks was evaluated by visual inspection. Marks *intensity* was scored on a 3-grade scale: 1 – "weak", 2 – "average", 3 – "good"(Fig. 1(a–d)). The grade distribution although subjective, can provide quite a good estimate of the overall performance of the technique.

Fig. 2(a) depicts the distribution of the *intensity* scores among the adult population. As can be seen, there is an approximately even distribution of scores, 33% developing "good" marks, and 29% developing "weak" marks. Fig. 2(b) depicts the distribution of the intensity grades among the children group. Obviously, a very significant percentage of the children population responded positively to the PDT reagent after contact. Notably, among this group, 64% developed "good" marks, whereas only 7% developed "weak" marks.

Fig. 2(c) provides a more refined analysis of the intensity score distribution among children. Here, the population is divided into three subgroups according to age: 6–8.5 years; 9–10.5 years; 11–15 years. Notably, the percentage of the population to whom the best ("good") score – in terms of intensity – was assigned, grows from 60% in the 6–8.5 years old to an impressive 75% among the 9–10.5 years old, declining to a 65% among the 11–15 years old.

In Fig. 2(d) we attempt to roughly delineate a correlation between age and iron impression intensity.

4. Discussion

In this study, we aimed to investigate the effectiveness of the PDT technique on children's hands. The investigation served two purposes. The first: to focus on an age group which has never been reported, regarding its reaction to the PDT test (the "age factor"). Studying this reaction is of relevance to the forensic science community, since this age group is involved in gun violence throughout the world.

The second purpose was to broaden our understanding of the physiological characteristics on processes involved in the detection of firearms contact impressions. Due to the advantages of the Ferroprint™ technique in forensic investigations, and given the fact that its application is already used as a routine procedure, it is important to understand the factors affecting the technique's sensitivity and efficiency.

The influence of several factors on the quality of iron-PDT marks, such as the gripping duration and the effect of washing the hands, has been reported earlier [19,20]. In a recent study two techniques which are based on better understanding of the physiological processes which take place on the skin, have been devised and tested for the enhancement of the sensitivity of this process: exposure to water vapors and accelerated sweating [28].

Regarding the role of the "physiological characteristics", the most significant finding of the present study was that children develop considerably better PDT impressions than adults.

Further studies are needed to fully elucidate the mechanisms that give rise to significant correlations between the quality of the iron impressions and age. It has been found that iron transfer to the hand is basically a chemical process. Palmar sweat dissolves iron oxide from the metallic parts of the object transferring it to the skin [21]. Thus, differences in the chemical composition of children's sweat in comparison with adults [29,30] can account for the high intensity of the iron marks developed on children's hands. The difference in the chemical composition of skin residues deposited by children from that of adults has been investigated as a part of a fingermarks visualization study [29]. Three major classes of

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