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Understanding the Influence of 0.22 Caliber Bullets on Different Types of Clothing Materials for The Estimation of Possible Caliber of Projectile

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Abstract *— Ballistics is defined as the study of projectile action, motion, and behavior in any given medium. The projectile travels down the barrel and in the medium towards the main target. In many severe crimes, firearms are the most widely used weapons. Forensic ballistics currently uses analytical techniques in the courtroom to ascertain the use of the suspected weapon in a particular crime and the technical advancement to measure and estimate the range of fire with greater precision along with the possible type of firearm used. The major concern arises in the cases where the firing happens through intermediate targets like clothing. Usually, the Gun Shot Residue (GSR) is present over the wound. Sometimes, the clothing items play a hindrance in the proper evaluation of the caliber of the weapon. The current work demonstrates the effect of 0.22 caliber bullets on different types of clothing using different types of firearms of the same caliber. It also indicates the approximation in the range of firing up to an extent. The main focus was given on the formation of entry and exit holes on different types of clothing material and then the deposition of GSR to study the effect. It was experimentally established that the size of the entry hole varies significantly on different types of clothing material, and the deposition of GSR and scorching pattern also shows noteworthy differences on various clothing materials.*

Keywords *— Ballistics, Firearms, 0.22 Caliber bullet, Clothing Material, Range of firing*

I. INTRODUCTION

Ballistics is defined as the study of projectile action, motion, and behavior in any given medium [1]. The projectile travels down the barrel and in the medium towards the main target. In many severe crimes, firearms are the most widely used weapons [2]. Forensic ballistics currently uses analytical techniques in the courtroom to ascertain the use of the suspected weapon in a particular crime and the technical advancement to measure and estimate the range of fire with greater precision along with the possible type of firearm used[3]. The major concern arises when the firing happens through clothing material [4, 21]. Heavy clothing can occasionally act as a collaborator to malformed and cover up a projectile, allowing it to curve or to deviate into pieces, leading to the formation of a temporary cavity that is larger and more superficial in comparison to the permanent cavity. Though there are no reliable figures available, it can be understood from various researches that many victims of gunshot injuries are shot through their clothing [5, 26]. The impact of bullets and the fabric layers used by victims and their effects on bodily injuries were studied by some researchers, and few of the researchers found that the cloth worn by the victim does not affect the actual wound size [6]. Many authors suggested that denim (representative of jeans) can aggravate the wound caused by high-velocity projectiles [7].

Further studies have also been conducted on the damage to the clothes due to various bullets types when fired at different ranges [8, 22]. Limited researchers have also compared the penetration of bullet into the clothed gel and unclothed gel under similar conditions and found that gunshots that did not penetrate the gel were used to estimate the possible stopping time of the pellet as well as the force or stress required to stop the pellet[9]. A few of the previous studies observed that even with low projectile energy, the clothe fibers were entrained in the gel, revealing the potential for penetrating the human body [10, 23]. Examining the fabric material is very critical in bullet wound situations. Interposing clothes between the gun's muzzle and the skin can alter the appearance of gunshot wounds in near-range shots [11]. The type of fabric worn by the victim plays a key role in dispersing the soot or powder from the gun between the various layers of the cloth [12]. Many a time, the soot or powder can be completely absorbed by the cloth material. In one research, Jason and Haag documented that fibers can and will protrude outward on the entry side of a bullet hole. The directional determination where the cloth is the first object encountered by the bullet was explained using the bullet wiping technique [13]. Few authors have found that the bullet wiping technique is the most reliable method to identify the entry site of the perforated cloth or object. Examining the cloth or fabric damaged by gunshot wounds should be carefully examined by the crime scene investigators[14].

Few other investigators have analyzed the effect of clothes on the size of gunshot wounds made by long-distance shots with small-caliber bullets [15]. In their work, they have done an experimental study which was made on estimation distance of shots made from far distance through clothes with 5.6-mm jacket-free lead bullets. Other researchers have concentrated on modeling textile obstructions imitating human clothes, and measuring the wounding bullet's contact velocity [16]. According to them, almost complete forensic-medical characteristics of inlet gunshot wounds of the body allowing for clothes properties, the anatomic structure of the affected body area, and deformation of the hitting bullets can be obtained[17]. According to one of the researchers, the bullet impact detection in the silhouette was proposed. This research anticipated a method for automatic detection of the bullet impacts in silhouettes based on deep learning and image processing, consisting of pre-processing, impacts detection, edge detection, and evaluation results [17]. Other researches have been performed to understand the bullet behaviour on fiber glass at different firing ranges to estimate the possible firing range by observing and analyzing the glass fractures [18, 24]. Investigators have also used Scanning Electron Microscopy (SEM) and Focussed Ion Beam Milling (FIB) for the detection of Gun Shot Residue (GSR) with the help of Cross-sectioning of particles to reveal the interior morphology and elemental profile of GSR [19]. In astonishing research, the range of firing determination has been achieved by studying the impact on Physiological Parameters like EEG, ECG, and Blood Pressure modalities [20]

II. MATERIALS AND METHODS

The major focus of the present study was to differentiate between the entry and exit hole based on the hole markings created on different types of clothing material with the help of physical, microscopical, and dimensional examination. The other emphasis was on determining the possible firearm (bullet) calibers from the bullet hole on the clothing material and studying the over the effect of the 0.22 caliber projectile on selected types of clothing (Cotton, Denim, Polyester) materials.

Based on the fact that as soon as the projectile leaves the gun's barrel, it brings out ejecta particles with it. These ejecta particles, collectively known as GSR, act as a means of firing range estimation and determining entry and exit wounds in terminal ballistics. GSR can be found embedded or distributed on to anything that comes in contact with the bullet or over the surrounding items in the close vicinity of the gun when it is fired. Also, it can be well understood that different types of clothing material will respond in a varying manner to GSR deposition.

A. Selection of Firearms: For this study, two particular firearms were used, i.e., CZ Bolt Action Rifle of 0.22 caliber and Smith and Wesson Revolver of 0.22 calibers.

B. Range of Firing: Both the firearms were discharged at a constant range of 10 meters from the target.

C. Selection of the Target: The target board was covered with cotton, denim, and polyester, respectively, during the experiment.

D. Number of Shots Fired: In total, 12 shots were fired on three different types of cloth materials from the two firearms as mentioned above. Out of this, six shots were fired from the Bolt Action Rifle and the other six shots from the Revolver. Therefore, four bullet holes were created on each piece of clothing, i.e., Cotton, Denim, and Polyester.

E. Place of Firing: The licensed personals conducted the firing under all precautious conditions in "Sharjah Shooting Range" UAE. The selected cloth materials adhered to the target board.

F. Photography of the Target After Firing: After firing, the cloth, along with the bullet mark, was then subjected to high-resolution photography along with image enlargement with the help of a DSLR – Nikon D5100 camera. Also, for further detailed examination, the stereomicroscope and UV light was used to study GSR. The major phenomenon studied were Scorching, GSR deposition, and Bullet wipes.

III. RESULTS AND DISCUSSIONS

As discussed in the above section, three types of cloth materials were selected, i.e., cotton, denim, and polyester. The materials were targeted at a distance of 10 meters using Bolt Action Rifle and Revolver of 0.22 caliber, respectively. The photographs were taken using a 35 mm DSLR camera. Further study was done under a stereoscopic microscope to study the fiber details and scorching.

Table I discusses the different physical characteristics occurring on the cotton cloth material due to two different firearms of the same 0.22 caliber. Observing the cloth materials under the stereomicroscope showed (fig.1 and fig.2) that the clothing material affected by the Bolt Action Rifle showed no singeing; although, the presence of bullet wipe and scorching were visible. However, the scorching was more prominently seen in the case of revolver firing due to the short barrel, which facilitates the early leaving of the projectile from the muzzle, resulting in more gases leaving with the projectile. It is noticeable that the diameter of the bullet hole varies slightly in both cases, even though the caliber of the projectile and distance of firing remains the same. In rifle, it shows approximately 5.3 mm whereas, in the case of a revolver, it becomes approximately 5.7 mm. This variation may be due to the difference in the velocity, as the bullet fired from the rifle possesses more velocity than the revolver bullet, passing more quickly through the clothing material and creating a slightly smaller entry hole.

TABLE I
SHOWING DIFFERENT PHYSICAL CHARACTERISTICS OCCURRING ON THE COTTON CLOTH MATERIAL DUE TO THE EFFECT OF TWO DIFFERENT FIREARM DISCHARGES

Target Material – Cotton Cloth		
Firearm Type →	**Bolt Action Rifle**	**Revolver**
Characters Studied ↓		
Diameter of The Entry Hole Formed	~5.3 mm	~5.7mm
Scorching Pattern	Less Prominent	More Prominent
Bullet Wipe Near Entry Hole	Present	Present
GSR Deposition Over the Entry Hole	Present (Less prominent)	Present (More prominent)
Margins	Inverted with numerous secondary fibers with less sooting	Inverted without or less prominent secondary fibers with more sooting
The shape of The Entry Hole	Circular	Irregular margins
Image	Figure 1	Figure 2

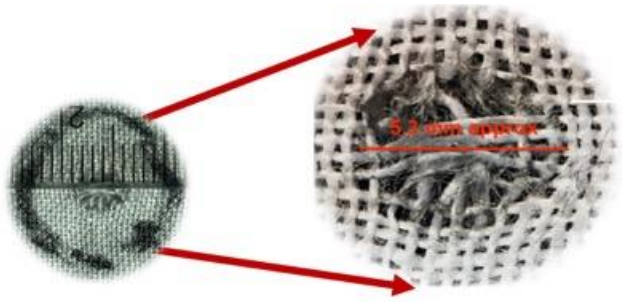

Fig. 1 – The normal and enlarged stereoscopic image of the bullet hole created by 0.22 caliber Bolt Action Rifle on a cotton cloth piece showing the diameter of the bullet hole.

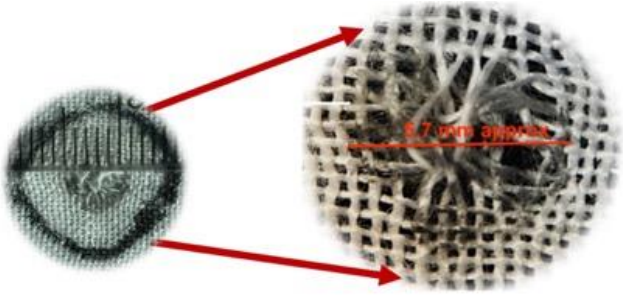

Fig. 2 – The normal and enlarged stereoscopic image of the bullet hole created by 0.22 caliber Revolver on a cotton cloth piece shows the diameter of the bullet hole.

In the rifle case, margins found were inward, and the shape of the bullet hole was moreover circular. On the other hand, the one affected by the revolver shows an increase in diameter, irregular margins with more sooting during the stereoscopic examination. GSR deposition seemed to be present in both cases; although, it was more prominent than the one by rifle.

Table II illustrates that in the case of bolt action rifle, the entry hole diameter was 5.2 mm approximately and in the case of a revolver, it was slightly increased to 5.5 mm approximately. This slight increase in the diameter of the entry hole may be due to the lesser velocity of the revolver projectile. The projectile takes slightly longer (though just for fractions of a second) than the high-velocity bolt action rifle projectile. Also, the entry hole diameter is minimum compared to the other clothing materials, i.e., cotton and polyester. This may be due to the less burning and melting effect of higher heat resistance in denim fibers. The scorching was more prominent in the bolt action rifle firing on the denim cloth than the revolver. The holes produced by both bolt action rifle and revolver on denim show bullet wipe because the soot adheres more on to denim.

TABLE II
SHOWING DIFFERENT PHYSICAL CHARACTERISTICS OCCURRING ON DENIM CLOTH MATERIAL DUE TO THE EFFECT OF TWO DIFFERENT FIREARM DISCHARGES

Target Material – Denim		
Firearm Type →	**Bolt Action Rifle**	**Revolver**
Characters Studied ↓		
Diameter of The Entry Hole Formed	~5.2 mm	~5.5 mm
Scorching Pattern	More Prominent	Less Prominent
Bullet Wipe Near Entry Hole	Present	Present
GSR Deposition Over the Entry Hole	Present (Less prominent)	Present (More prominent)
Margins	Inverted with numerous secondary fibers with less sooting	Inverted without or less prominent secondary fibers with more sooting
The shape of The Entry Hole	Circular	Irregular margins
Image	Figure 3	Figure 4

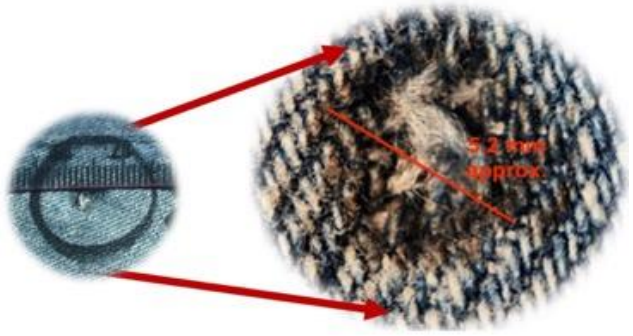

Fig. 3 – The normal and enlarged stereoscopic image of the bullet hole created by 0.22 caliber Bolt Action Rifle on Denim cloth piece showing the diameter of the bullet hole.

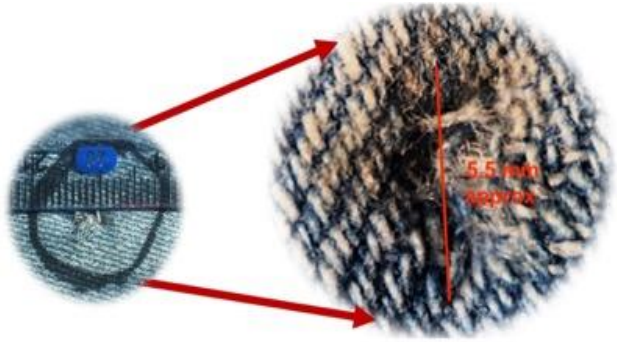

Fig. 4 – The normal and enlarged stereoscopic image of the bullet hole created by 0.22 caliber Revolver on the Denim cloth piece shows the bullet hole's diameter.

The presence of GSR on the cloth with the hole created by the revolver is more than on the one created by the bolt action rifle due to the low velocity of the projectile, and the projectile has more chance to be in contact fractionally than the bolt action rifle projectile. Like the other entrance holes, for both bolt action rifle and revolver, the margins are inward. But on careful examination, the hole created by the Bolt Action Rifle shows the outside reversal of fibers, whereas, in the case of revolver firing, all the fibers went inside. The microscopic examination did not reveal any singeing of the denim cloth, as was the cotton case. The shape of the bullet hole in a bolt action rifle is different from the revolver. The bolt action rifle gives a circular shape, whereas the hole created by the revolver shows an irregular shape.

Table III summarizes the effects of 0.22 caliber projectile on a piece of polyester clothing. After firing, the shape of the bullet hole was seen to be oval for both a bolt action rifle and a revolver with irregular margins. The diameter of the bullet hole for the bolt action rifle was observed as approximately 5.4 mm and 5.7 mm for the revolver. The margin of the bullet hole was inverted in both cases. Scorching was also encountered in both cases. The scorching is comparatively greater than the other two clothing materials, i.e., cotton and denim. This may be due to the lesser heat resistance capacity of polyester fibers. However, as the fig.5 and fig.6 portrays, the size of the bullet hole is slightly larger in revolver firing in comparison to bolt action rifle firing; it is again can be understood that the revolver bullet, due to low velocity, tends to stay in contact with the polyester clothing more than the bolt action rifle bullet and creating slightly larger bullet hole. GSR was found to be more prominent in the case of the entry hole made by the revolver compared to the one made by the bolt action rifle.

TABLE III
SHOWING DIFFERENT PHYSICAL CHARACTERISTICS OCCURRING ON POLYESTER CLOTH MATERIAL DUE TO THE EFFECT OF TWO DIFFERENT FIREARM DISCHARGES

Target Material – Denim		
Firearm Type →	**Bolt Action Rifle**	**Revolver**
Characters Studied ↓		
Diameter of The Entry Hole Formed	~5.4 mm	~5.7 mm
Scorching Pattern	More Prominent	Less Prominent
Bullet Wipe Near Entry Hole	Present	Present
GSR Deposition Over the Entry Hole	Present (Less prominent)	Present (More prominent)
Margins	Inverted and less prominent	Inverted and more prominent
The shape of The Entry Hole	Oval	Oval
Image	Figure 5	Figure 6

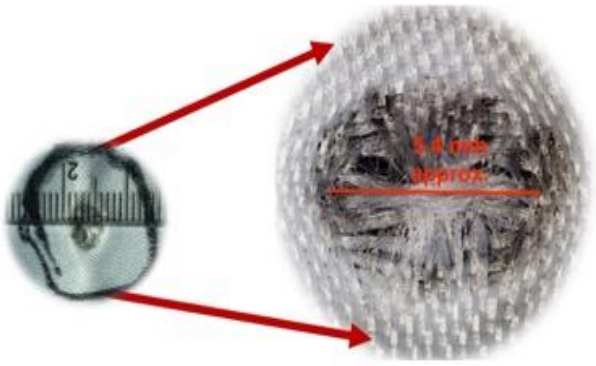

Fig. 5 – The normal and enlarged stereoscopic image of the bullet hole created by 0.22 caliber Bolt Action Rifle on Polyester cloth piece showing the diameter of the bullet hole.

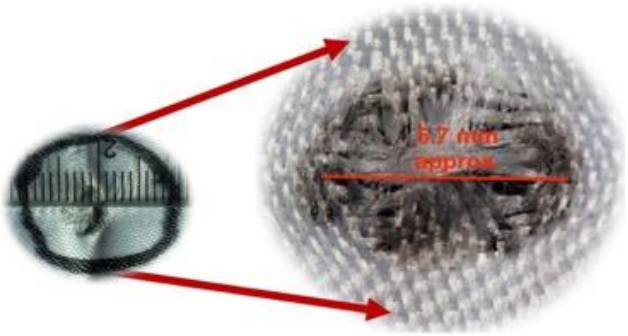

Fig. 6 – The normal and enlarged stereoscopic image of the bullet hole created by 0.22 caliber Revolver on Polyester cloth piece shows the bullet hole's diameter.

It is clear from the above observations that entry holes created by bolt action rifles are usually smaller in comparison to revolver projectile, irrespective of the clothing material as we know that the caliber of the firearm and the projectile was kept constant, i.e., 0.22 caliber, along with the constant distance of 10 meters for the study. The smaller entry holes created by bolt action rifle projectiles show the impact of high velocity, as the bullet passes through the clothing material much faster than the revolver projectile.

IV. CONCLUSIONS

The presence of clothing plays an important role in the analysis and identification of the caliber of the firearm in a shooting incident. As many of the Shooting incidents around the world occurs through different types of clothing material. It is also evident that layers of clothing contribute significantly to the wounding caused by a projectile. Though, the type of firearm, the type of projectile, the distance of firing, and the projectile's velocity are considered major factors in wounding. Anyhow, despite these factors, the type of the clothing material is considered during the determination of possible caliber of firearm and projectile. There are cases where only clothing items are encountered at the scene of a crime or in surrounding areas. In such cases, caliber determination becomes a difficult task for the investigators. The proposed study is an approach towards estimating possible caliber by analyzing the entry hole on cotton, denim, and polyester cloth material. However, the study was limited to the distance of 10 meters, use of 0.22 caliber bolt action rifle and revolver, and to the selected clothing material, i.e., Cotton, denim, and polyester. The result may differ if the single layer is changed by the multiple layers of the clothing material with a varying firing range as it was observed in the study that low-velocity projectile like from revolver cause slightly larger entry hole on all three types of selected clothing material in comparison to the high-velocity projectile [27]. This indicates that low-velocity projectiles have more contact time(fraction of second) than high-velocity projectiles [28]. The scenario may entirely be different when the range of firing varies from the constant value that has been taken in this present study. The stereomicroscope is very useful in determining the possible caliber of the firearm, studying the phenomenon occurring over the clothing material, and studying the behavior of the fibers of different clothing during firing. Thus it is the dire need of the hour to give equal importance to fabric evidence as given to the firearms, projectile for the determination of caliber in suspected ammunition cases.

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FUTURE SCOPE

This study was not exhaustive and the results observed were relative and comparative. However, further studies can be done on more bullet holes on similar or on different cloth materials produced from various firearm discharges for more accuracy.

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