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Effects of Shooting Angles and Ricochet Angles on Bullet Weight Upon Impact on Three Types of Woods (Balau, Resak, and Seraya)

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ABSTRACT

This study aims to determine if the number of shots fired, bullet striation marks, and shooting and ricochet angles could influence bullet weight on three types of woods: Balau, Resak, and Seraya. The weapon and ammunition used in this study were CZ 75 SP-01 Shadow semi-automatic pistol with 9 mm full metal jacketed bullets (7.45 g). A total of 432 shots were fired, and only 114 bullets produced a ricochet effect. The result of objective one showed no significant relationship between the number of shots and the number of bullet striations for all three kinds of wood. Correlation-Regression analysis for the second objective showed a significant relationship between shooting angle and bullet weight when shooting on Balau ($p < 0.01$, $R^2 = 0.065$) and Seraya ($p < 0.01$, $R^2 = 0.199$) but not on Resak. The shooting angle influenced the bullet weight by 6.5 % to 20 % when shooting on Balau and Seraya. Both kinds of wood are closely related and share fibre composition and modulus of elasticity (MOE) characteristics. The result of the third objective showed a relationship between ricochet angle and bullet weight during the shooting on Resak ($p < 0.01$, $R^2 = 0.142$) but not on Balau and Seraya. The ricochet angle on Resak influenced the bullet weight by 14.2 + 9.8 %. It is probably due to Resak having the highest MOE among the three types of woods. This study concludes that bullet weight loss is due to the ricochet effect and the composition of the bullet's target.

Keywords: Balau, Resak, ricochet, Seraya, shooting angle

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INTRODUCTION

A ricochet effect can occur when a bullet hits a hard target surface. The risk of this phenomenon is exceptionally high when Maritime Enforcement officers board a ship and clear off potential suspects in a closed compartment. According to Brian (2008), when a bullet strikes any surface, there is a critical angle at which it will bounce off or ricochet from the surface rather than penetrate it (Maho et al., 2019; Hamzah et al., 2020). A ballistic reconstruction based on the ricochet effect of bullets can help provide insight into whether that particular enforcement officer is legally responsible for the accidental death of the victim (Nishshanka et al., 2020). The reconstruction of a shooting scene can provide helpful information for investigating officers in solving a crime by evaluating the evidence available, thus deducing what had possibly happened during the shooting incident (Mahoney et al., 2019). Crime scene investigation (CSI) experts have reported that when a bullet is fired, a reduction of bullet weight will occur, particularly after the shooting is made at an angle. It is further postulated that weight loss will occur due to the ricochet effect of the bullet (Nichols, 2018). However, previous studies regarding the impact of ricochets on bullet weight are sparse. Furthermore, it is suspected that the loss of bullet weight due to the ricochet effect is influenced by the composition of the bullet's target (Kpenyigba et al., 2015; Koene & Broekhuis, 2017).

In 2017, fishing vessels plying on seas around Southeast Asia were reported to be around 1,270,000. Studies have shown that these boats are built mainly from Balau, Seraya, and Resak woods (Malaysian Timber Council, 2020a, 2020b, 2020c; Wahab & Ramli, 2020). These vessels are small compared to commercial fishing vessels as they usually have a dimension of around 10 to 15 m in length with a beam of approximately 6.1m (Atzampos et al., 2018). Due to their relatively small size, small water displacement, and commonly found around ocean boundaries between countries, their movement on the sea is relatively unhampered by shallow waters or close monitoring by enforcement agencies (Dang et al., 2018).

Most fishermen are law-abiding men, but a few would supplement their meagre income with illegal activities (United Nations Office on Drugs and Crime, 2011; Mackay et al., 2020). Consequently, lately, Malaysian Maritime Enforcement Agencies (MMEA) within the region have started to conduct frequent random boarding to ensure the vessel's cargo is legal. In rare cases, shooting will occur when enforcement officers approach the craft, board the boat, or conduct searches within the boat (Abbo, 2021).

Although the vessels are small, compartments inside the boat are present to provide a watertight space. It is made in such a way as to allow privacy and further strengthen the vessel's structure. Due to this, unethical fishermen will create hidden panelling. In these panels, illegal drugs would be hidden from sight and, if sufficiently large enough – humans. During the search below deck, shooting could occur, and due to the relatively small area of each compartment, the shooting would be at an angle and a close distance (less than 10 m) (Dang et al., 2018).

Timber refers to the stage where a woodblock is cut from a fallen tree and is ready for further processing. However, there might be a presence of variability in its mechanical properties due to it being a biological material. Thus, strength grouping was proposed for the timbers to standardise their mechanical properties. This standardisation facilitates the selection of suitable timber for structural purposes. The strength grouping of tropical hardwood timber can be classified into strength groups (SG) A to D, based solely on compression strength parallel to the grain. This study's target of interest is the material used to build local fishing vessels: Balau, Resak and Seraya.

Balau (*Shorea* spp.) is a heavy, dense hardwood with the strength properties of Group A (Asyraf et al., 2021). It is a solid timber with a compressive strength of above 55.2 MPa. The wood is also highly durable resulting in relatively high resilience towards heavy impact forces cast by the sea. Hence, it is commonly used in wooden boat construction in Malaysia.

Resak (*Vatica* spp.) is a hard and heavy wood classified under Group B. Timber classified under-strength properties of Group B are very strong woods with a compressive strength mean of 7.52 MPa (Puaad et al., 2020). However, Resak from Strength Group B has lower strength properties when compared to that Balau, which is in Strength Group A.

On the other hand, Seraya (*Shorea* spp.), commonly known as Dark Red Meranti, is a light hardwood that is moderately durable (Widiyono, 2021). The strength properties of Seraya wood fall in Group C. Group C timbers are strong and have a compressive strength of between 27.6- 44.3 MPa. Despite being the lightest hardwood among the three types of wood investigated in this study, the relatively lightweight properties of Seraya enable better buoyancy than the rest (Dewi et al., 2020). Table 1 shows the characteristics of Resak, Balau and Seraya.

Table 1
Characteristic of woods

Wood type	Woods classification	Strength properties group	Compressive strength (MPa)
Balau	Heavy Hardwood	A	55.2
Resak	Heavy Hardwood	B	7.52
Seraya	Light Hardwood	C	27.6–44.3

Based on the Malaysian Timber Council, Balau wood, known by its scientific name *Shorea* spp., is a heavy hardwood with a density of 850-1,155 kg/m^3 air dry (Malaysian Timber Council, 2020a). It has a Janka Hardness of 8,010-9,520 N. Resak wood with the scientific name of *Cotylelobium* spp. and *Vatica* spp. (Dipterocarpaceae) is also a heavy hardwood with a slightly lower density than Balau wood. The density for Resak wood is 655–1,155 kg/m^3 air dry with a Janka Hardness of between 2,570 to 8,990 N. Meanwhile, Seraya, the scientific name of *Shorea curtisii*, is a light hardwood with a density of around 415 to 885 kg/m^3 air dry. The Janka Hardness for Seraya wood is usually between 1,020 to 4,480 N (Table 2).

Table 2
Properties of woods

Wod	**Balau (*Shorea* spp.)**	**Resak (*Vatica* spp.)**	**Seraya (*Shorea* spp.)**
Type of wood	Heavy hardwood	Heavy hardwood	Light hardwood
Strength properties of Wood	Strength Group A	Strength Group B	Strength Group C
Janka Hardness (N)	8,010-9,520	2,570-8,990	1,020-4,480
Density (kg/m^3 air dry)	850-1,155	655-1,155	415-885
Modulus of Elasticity (MPa)	16,670	19,500	13,020
Wood grain	Deeply interlocked	Straight or shallowly interlocked	Interlocked
Fibre structure (Texture)	Moderately fine to slightly coarse	Fine and even	Moderately coarse and even
Fibre composition (%)	27	No relevant information	25

Numerous previous studies have been performed regarding a bullet's ricochet effect. Koene (2016) demonstrated in their study that there would be at least 70% of energy loss to the projectile due to ricochet. There will be a more significant energy loss when shooting on harder wood types than a softer wood. Kerkhoff et al. (2015) showed that 50% of fired bullets (.32 Auto and 9 mm Luger) would experience a ricochet effect when a critical angle is reached. Further, the effect is influenced by the weapon calibre and composition of the target drywall (Walters & Liscio, 2020). Their study also found a strong linear relationship between the critical angle, wood density and Janka Hardness. It was further noted that to create a ricochet effect, and the critical shooting angle increases in parallel with the value of the wood's Janka Hardness (Wong & Jacobson, 2013). They reported that the correlation coefficients in their study were 0.997 (density, .32 Auto), 0.985 (density, 9 mm Luger), 0.987 (Janka Hardness, .32 Auto) and 0.962 (Janka Hardness, 9 mm Luger) (Table 3).

Table 3
Bullet correlation coefficients

Cartridges with full metal jacket bullets	**.32 Auto**	**9 mm Luger**
Correlation Coefficients	0.997	0.985
	0.987	0.962

It was also noted that the shooting angle for smaller calibre bullets is higher, as seen in the higher correlation coefficient of .32 Auto bullets compared to 9 mm Luger bullets when shooting on wood with the same density and Janka Hardness.

Nordin et al. (2020) reviewed the forensic significance of gunshot impact marks, including the study of bullet striation after a ricochet effect. Their review highlighted the importance of viewing forensic investigation on a case-specific basis due to the unpredictable difference between real-case shooting scenarios versus controlled studies. They also emphasised the lack of synchronisation and comparable data among current researchers, which leads to difficulties in predicting the bullet's behaviour during shooting reconstruction when a different combination of ammunition and target materials is involved.

Relating to that, this study's main focus is the number of shots fired, bullet striation marks, bullet weight, shooting angle and ricochet angle. The weapon and ammunition used in this study are commonly used by the Malaysian Maritime Enforcement Agency (MMEA) officers (Wahid, 2020; Agensi Maritim Luar Negara, 2019).

It is suspected that the ricochet effect of the bullets would differ after hitting different target surfaces (Nishshanka et al., 2021a). This phenomenon is essential in the forensic context as the impact of firing may vary due to the nature of the target surface, different shooting angles, and distances (Liscio & Imran, 2020). Therefore, this research aims to create an equation model that includes all the factors, including bullet striation marks, shooting angles and ricochet angles, allowing maritime CSI to create a near-accurate ballistic reconstruction scene.

MATERIALS AND METHODS

Firearms and Ammunition

A Czech Republic-made CZ 75 SP-01 SHADOW series semi-automatic pistol with 9mm FMJ bullets were selected. They are commonly used by the Malaysian Maritime Enforcement Agency (MMEA) officers (Wahid, 2020; Agensi Maritim Luar Negara, 2019). It is a standard weapon used during ships' boarding and clearing out potential suspects in small compartments. CZ 75 SP-01 semi-automatic pistol is a reliable weapon with a drop-safe feature that prevents accidental discharge.

Wood

Balau, Resak and Seraya wood were selected as the target surface for this study. They are the three common types of wood used to manufacture fishing boats in Southeast Asia (Murdjoko et al., 2016; Cvetković et al., 2019; El-Taguri et al., 2020; Muslich & Sumarni, 2006; Abdullah, 2015).

Shooting/ Firing Protocol

The pistol was placed in a weapon mount with a string attached from the firearm's trigger to the place of release. Each of the three wood selected for the study (Balau, Resak and

Seraya wood) was clamped on an adjustable stand, with a fixed distance and a variable angle of 15°, 30°, 45°, 60°, 75° and 90° from the position of the gun. Next, a 9 mm FMJ bullet was loaded into the pistol. Then, a string connected to the trigger was pulled. The use of the string is to isolate the recoil effect of the weapon and indirectly improve the bullet's momentum. After each shooting, the fired bullet was searched, labelled, and packaged for further examination.

A minimum of 24 replications was conducted for each of the shooting angles. At each of the shooting angles (15°, 30°, 45°, 60°, 75° and 90°), the distance between the pistol and wood was 5 meters from the target. The shooting angles and distance were chosen based on the limited space available in a fishing boat. The main point of this study was to get the weight of the bullet after being fired (ricochet and penetrate). Hence, 144 shots were made on each type of wood.

The first study objective was to determine the relationship between the number of shots fired against bullet striation marks on different types of wood (Balau, Resak and Seraya). It is suspected that during multiple shots, the barrel within the weapon will heat up, making the inner wall of the barrel become soft. It causes striation marks to be easily developed when firing occurs. When the barrel cools down sufficiently enough, these newly created striation marks within the barrel will solidify. The newly created striations will cause the next bullet to have additional striations. Objective 1 examined the relationship between the number of shots and bullet striations. Thirty fired bullets shot at each wood were selected through random sampling. It was possible as each bullet shot was recorded, and shooting was done in batches: Balau, Resak and Seraya. It allowed us to select 30 bullets randomly in every wood group and still determine when the bullet was shot (sequence number) and the number of striations created. Samples were collected randomly. The sample selection was made by a third party to minimise biases. Thirty samples were selected based on statistics' Central Limit Theorem.

The bullets were then placed on a bullet holder, and the striation marks were examined under a LEICA DM2500M Compound Microscope. A Canon EOS 3000D was used in this research to capture the picture of bullets. As the bullet was not discharged previously, no striation marks were present on the bullet. The images of each side of the bullet's striation marks were captured through a camera attached to the compound microscope. The number of striations counted was based on striations visually observed under a compound microscope. The number of striations counted is based on an imaginary horizontal line created at 10% length of the existing bullet starting from the bottom of the bullet (Leon & Beyerer, 1999). The captured images of the bullet's striation marks were then further analysed with the help of ImageJ (Fiji) Windows 64-bit version software to analyse the number of striation marks present. Correlation-regression analysis was performed with a level of the significant set at $p < 0.05$.

The second objective determined the relationship between the shooting angle and the bullet weight when shooting on different types of wood: Balau, Resak and Seraya. In this research, all bullets were from the same manufacturer. Every bullet's weight was around 7.45g. Digital scales were used to determine the weight of the bullet after a shooting. A total of 432 shots were fired. The bullets were then retrieved and weighed. A correlation regression test was carried out for all the data of bullet weight for each type of wood.

The third specific objective was to determine the ricochet angle and the bullet weight during a shooting on different types of wood: Balau, Resak and Seraya. After the shots were fired, the ricochet angle for bullets with a ricochet effect was measured using basic trigonometry (Nishshanka et al., 2021b; Mattijssen et al., 2017). The angle measuring tool used was the Raymay Zero Base Protractor (Raymay Japan). The ricocheted bullets were also weighed using procedures similar to Objective 2. Again, a correlation regression analysis was conducted to analyse the data generated for each type of wood.

RESULTS

Bullet Striation Marks

Correlation analysis was conducted to determine the relationship between the number of striation marks and the sequence of shots fired on different types of wood (Balau, Resak and Seraya). A number system was used for each shot to avoid errors in identifying bullets and wood. The results of the correlation analysis showed that it is statistically insignificant for all three types of wood. The *p*-values for Balau, Resak and Seraya were 0.076, 0.673, and 0.331, respectively. Hence, we concluded no correlation between the striation marks of bullets when fired at different types of wood. The relationship between the number of shots fired and the number of bullet striation marks on Balau, Resak and Seraya is illustrated in Figures 1, 2 and 3.

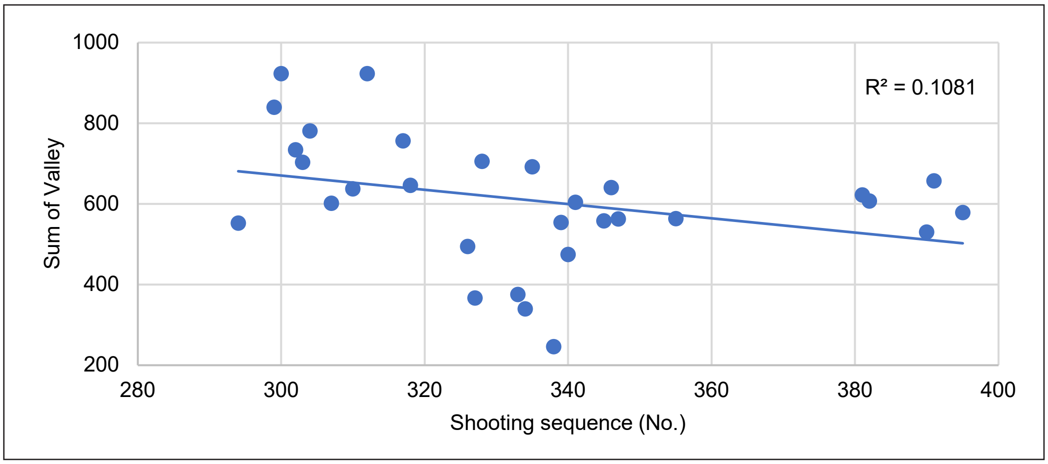

Figure 1. The relationship between the number of shots fired and the number of bullet striation marks on Balau

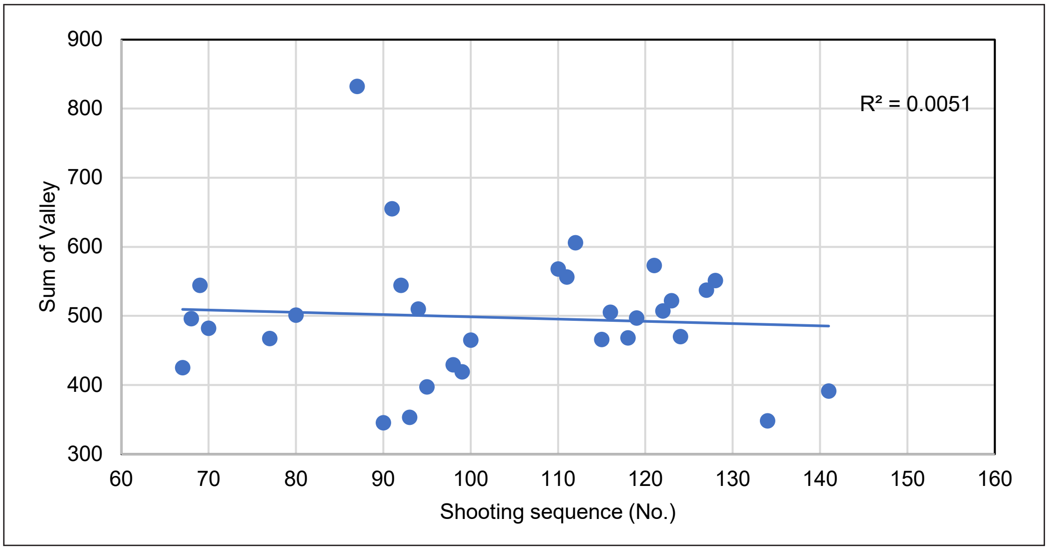

Figure 2. The relationship between the number of shots fired and the number of bullet striation marks on Resak

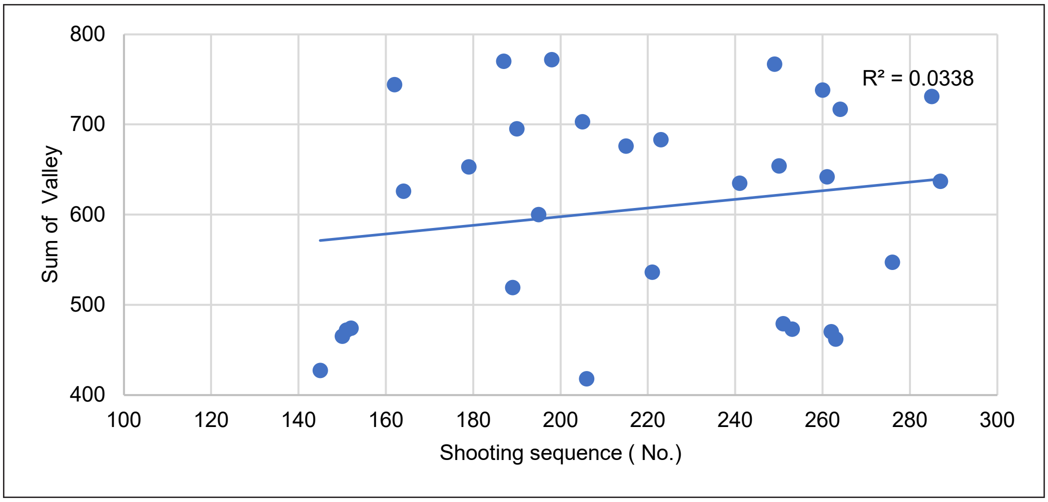

Figure 3. The relationship between the number of shots fired and the number of bullet striation marks on Seraya

Shooting Angle

The results of the Correlation-Regression analysis showed that Balau ($p < 0.01$, $R^2 = 0.065$) and Seraya ($p < 0.01$, $R^2 = 0.199$) have a statistically significant relationship between the shooting angle and bullet weight during shooting, but not for Resak ($p = 0.977$). This factor is related to the strength properties of the wood. Thus, only Balau and Seraya's shooting angle and bullet weight equations were formulated. For Balau, Bullet weight (g) = 0.001 × Shooting angle (SA°) + 7.428; 15° > SA > 90°. Meanwhile for Seraya, Bullet weight (g) = 0.001 × Shooting angle (SA°) + 7.437; 15° > SA > 90°. Although a significant relationship between shooting angle and bullet weight for Balau and Seraya was observed, shooting angle was only able to influence 14.19% and 19.87% of the outcome of the bullet weight. The weight of a bullet upon impact onto a surface might also be influenced by other possible contributing factors, such as the position of the wood's vein, variation of wood strength and the slight deviation of bullet trajectory immediately after shooting due to the gun recoil effect (Koene & Broekhuis, 2017; Karger et al., 2001; Vermeij et al., 2012). The relationship between the shooting angle and bullet weight when shooting on Balau and Seraya is illustrated in Figures 4 and 5.

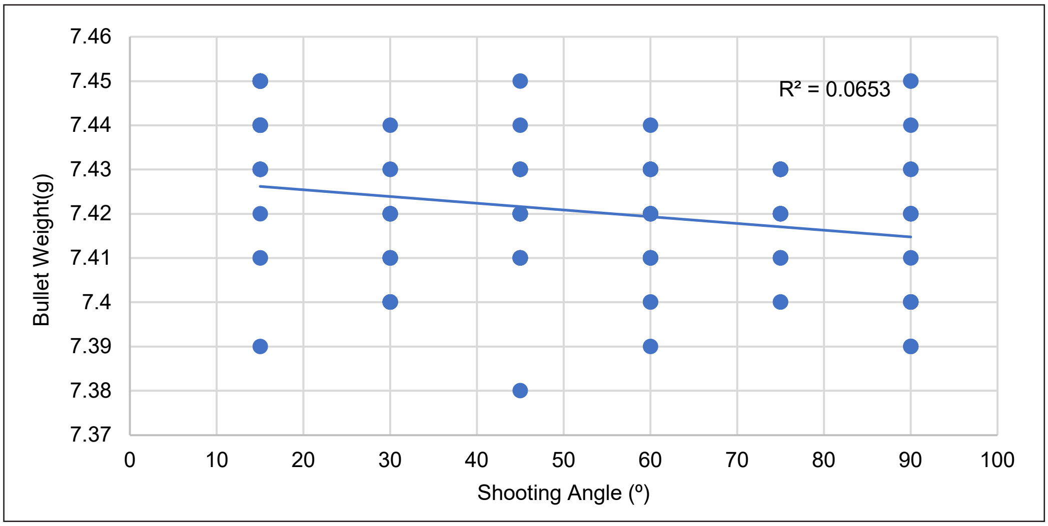

Figure 4. The relationship between the shooting angle and bullet weight when shooting on Balau

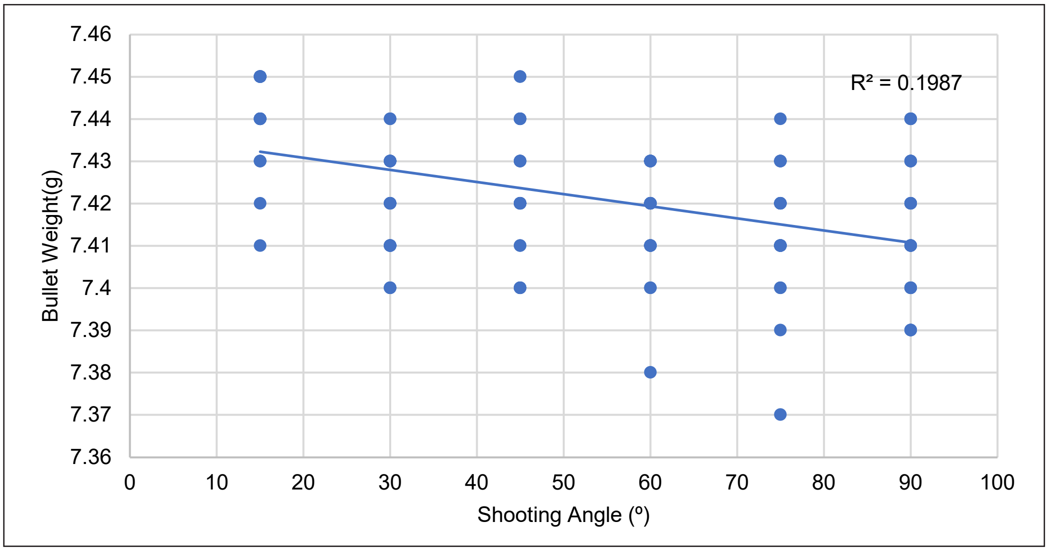

Figure 5. The relationship between the shooting angle and bullet weight when shooting on Seraya

Ricochet Angle

Correlation- Regression analysis showed a significant relationship for Resak between ricochet angle and bullet weight after shooting ($p < 0.05$, $R^2 = 0.1419$) but not for Balau and Seraya ($p = 0.835$ and $p = 0.099$, respectively). The equation of bullet weight generated for Resak is, Bullet weight (g) = -0.001 + Ricochet angle (RA°) + 7.458; 10° > RA > 66°. The relationship between the shooting angle and bullet weight when shooting on Resak is shown in Figure 6.

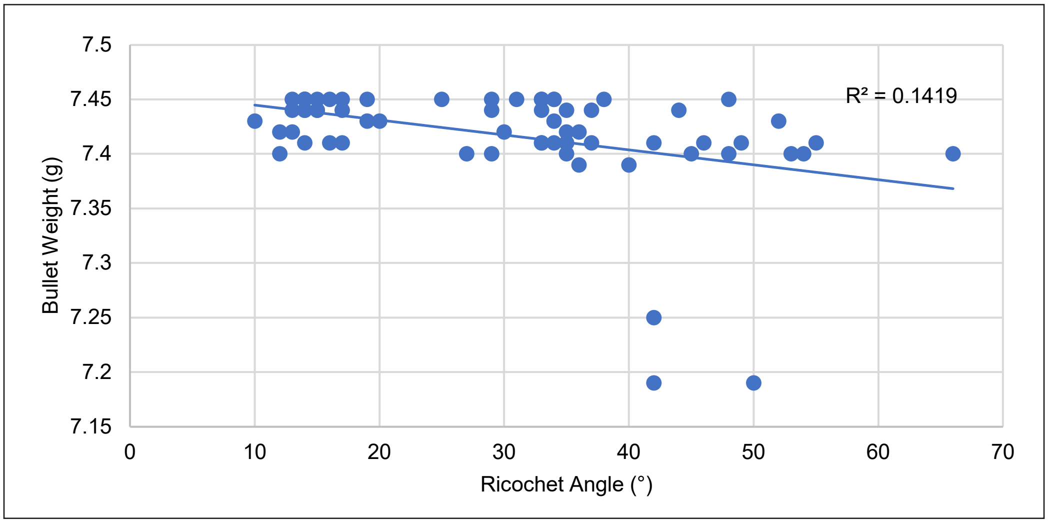

Figure 6. The relationship between the ricochet angle and bullet weight when shooting on Resak

DISCUSSION

Number of Shots Fired vs Bullet Striation Marks

The unique striation marks on the bullets are individual characteristics that can help to link a fired bullet to a specific firearm (Mahanta et al., 2019; Hamzah, 2016). In the past, ballistics experts have postulated that when a gun barrel is used multiple times without cleaning, multiple grooves within the gun barrel will form. There is not much information on how grooves are formed within a gun barrel after manufacturing it. It is suspected that the barrel within the weapon will heat up during multiple shots, making the inner wall of the barrel soft. It causes groove marks to be easily developed when firing occurs. When the barrel cools down sufficiently enough, these newly created groove marks within the barrel will solidify. The newly created groove will cause the next bullet to have additional striations.

When sufficient grooves are in the barrel, experts suspect a bullet passing through the barrel will lose significant weight. In essence, the grooves will shave some metal from the bullet. It will cause the bullet to be much lighter than before it was shot.

This study's outcome showed no significant relationship between the number of shots fired and bullet weight when shooting at Balau, Resak or Seraya targets. It indicates that the difference in the number of striation marks after multiple shots was insufficient to cause significant changes that would lead to the shift in bullet weight and indirectly to the identification of a specific weapon. It was consistent with the study, which reported that although the markings on the bullet continued to change, the 4000^{th} bullet was identifiable as the first bullet (Doelling, 2001).

A similar outcome could be due to the similar composition of barrels used for both studies. The barrel of the CZ 75 SP-01 semi-automatic pistol used in this study and the 9 x18 mm calibre Makarov semi-automatic pistol used were made up of 4150 Carbon Steel bullets (Doelling, 2001). A similar steel composition of molybdenum and chromium had made the barrel much harder than other pistol brands. The "41" in the first two numbers of the barrel steel refers to chromium-molybdenum steels, which contain 0.15-0.25% molybdenum and 0.80-1.10% chromium in their composition. Meanwhile, the "50" on the last two numbers refers to the amount of internal carbon content, which is 0.50%. 4150 Carbon Steel. This steel is generally tougher and more resistant than regular carbon steel (Liscio & Imran, 2020). Hence, this might have likely contributed to the insignificant increase of bullet striation marks as the number of shots fired increased.

Shooting Angle

The original weight of the 9 mm FMJ bullet used in this study was 7.45 g. For each shooting angle of 15°, 30°, 45°, 60°, 75° and 90°, a minimum of six shooting replications were made from four fixed shooting distances (1, 3, 5 and 10 meters). The shooting angle was used to compare whether shooting angles or ricochets affect bullet weight.

According to Kerkhoff et al. (2015), when a bullet hits on wood at various angles, which is softer than itself, it will either penetrate (lodge itself in the object), perforate (penetrate and exit from a surface other than the impact surface), or ricochet (bounce off from the impact surface). Irrespective of the outcome, there will be kinetic energy and deformation loss. Deformation of the bullet will sometimes cause shearing, leading to bullet weight loss.

The outcome of this study supported the study mentioned above. The result showed a significant relationship between shooting angle and bullet weight when shooting on Balau and Seraya. Unfortunately, no significant relationship was seen in Resak. Resak has the lowest wood compressive strength compared to the other two kinds of wood. Referring to Figures 4 and 5, the equation for the weight of bullets generated for Balau is Bullet weight (g) = 0.001 × Shooting angle (°) + 7.428; 15° > SA > 90°, whereas, for Seraya, the equation is Bullet weight (g) = 0.001 × Shooting angle (°) + 7.437; 15° > SA > 90°. These equations represent the Influence of the wood, shooting angle and shooting distance on bullet weight after the shooting. It was further noted that the shooting angle would influence the bullet weight by 6.5 % ($R^2 = 0.065$) and 4.2 % ($R^2 = 0.142$) when shooting onto Balau and Seraya wood, respectively. However, we would like to highlight that this equation only applies to firing a 9 mm FMJ bullet on the two wood types. It is suspected that a different combination of ammunition and wood type might result in a different result of bullet weight loss. For instance, the combination of .32 Auto bullets and Abachi wood used in the study led to different results in bullet weight loss than in this study (Kerkhoff et al., 2015).

Furthermore, the result variation between the woods could be explained as Balau and Seraya belonging to the same genus (*Shorea* spp) while Resak is from *Vatica spp*. Despite these two kinds of wood (Balau and Seraya) having a hardness at two extreme ends—Balau is a heavy hardwood while Seraya is light hardwood. Balau and Seraya are closely related and share similar characteristics, such as fibre composition and MOE.

In addition, both the woods from *Shorea* spp. have the same type of grain alignment called interlocked grains. Resak, on the other hand, is structured as straight or shallowly interlocked grains. Interlocked grain refers to how the wood grain spirals around the axis of the tree. The spiral reverses its direction for a certain period, resulting in alternating directions of the spiral grain (Slater & Ennos, 2015). Due to these characteristics, Balau and Seraya are the hardest wood to work within the wood-based industry and hence are highly sought after because the interlocking wood grain patterns improve overall wood strength properties (Slater & Ennos, 2015). Concerning the characteristics, the improved strength could have further caused more deformation towards the bullet and resulted in significant bullet weight loss after being shot at the angles.

On the contrary, Resak has a straight grain. The grains run in a single direction parallel to the tree's axis. During shooting, the bullet might have been forced to follow the softer wood cell structures along the direction of the wood grain and hence be deflected from its original trajectory. It, in turn, leads to lesser bullet deformation (Mattijssen et al., 2016).

It is also important to note that the grain alignment will cause the bullet to have a higher tendency to form indentations on the wood. In contrast, the frequency of bullet ricochets is more likely to occur with the increased value of the wood's elasticity. Consequently, bullets will bounce from the wooden surface due to a ricochet effect. The ricochet effect is closely related to wood elasticity. The issue of word elasticity will be discussed further, as the shooting and ricochet angles are closely interconnected.

Ricochet Angle

The Ricochet angle is where the bullet hits the wood and ricochets off the surface. A significant relationship exists between the ricochet angle on the bullet weight when shooting on Resak but not Balau and Seraya. Of 144 shots fired on Resak, 66 bullets had a ricochet effect. Based on Figure 6, the equation generated for bullet weight for Resak (Bullet weight (g) = -0.001 × Ricochet angle (°) + 7.458) is only applicable for ricochet angles of 10°

to 65°. The ricochet angle influenced the bullet weight by 14.2%. The remaining 85.8% indicates that other factors could affect the bullet weight, which is yet to be determined when shooting on Resak.

This finding might be due to the wood elasticity, often referred to as the MOE or Young's modulus. Technically, MOE is the measurement of the ratio of the stress (force applied) over the strain (deformation) on the wood (Meier, 2019). Resak, with an elasticity of 19,500 MPa, has the highest MOE. On the other hand, Balau and Seraya have an elasticity of 16,670 MPa and 13,020 MPa, respectively. The relatively high elasticity of Resak compared to the other two types of wood might result in more bullets experiencing a ricochet effect instead of burying into the wood (Azlan et al., 2018).

Concerning the above, wood is strongest in the direction parallel to the grain (Fu et al., 2021). However, our study had not considered the horizontal and vertical grain of the wood during the shooting process. Shooting on horizontal grain is referred to as parallel to the grain, whereas if on grain that shows vertical direction, it will be referred to as perpendicular to the grain. Therefore, if the bullet hits the wood positioned in the direction with horizontal wood grains, there will likely be more bullet weight loss. Thus, it is essential to note the direction of the wood grain when positioning wood before shooting for future research.

CONCLUSION

The factors influencing the bullet weight during shooting include the shooting angle, ricochet angle and the type of wood used. However, expanding its database using other kinds of weapons, bullets, and words would benefit forensic investigators, particularly when reconstructing a scene involving the discharge of a firearm.

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