Rifle Burst Fire Testing - Probability of Number of Impacts on Hard Armour Panel

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Abstract. This study aimed to evaluate the feasibility of firing 6-8 bullets on a 1000 sq. cm bullet-resistant panel from a distance of 10m using a three-bullet burst fire mode of a modern rifle. The results showed that firing three bullets in burst mode within 25 mm was not feasible, but firing three bullet bursts in 25-100mm was possible. Furthermore, the study compared different rifles and found that the Avtomat Kalashnikova-47 (AK-47) was more suitable than other rifles for burst fire mode, with a higher energy density noted for bursts using the AK-47 than Indian Small Arms System (INSAS) rifle. In the case of SIG Sauer 716, its larger cartridge size and resulting higher recoil make it more difficult to aim accurately. The study concluded that highly trained military personnel could accurately fire 6 bullets on a 1000 sq. cm hard armour panel (HAP) in accordance with National Institute of Justice (NIJ) 0101.06 or Bureau of Indian Standards (BIS)17051:2018 standards from a distance of 10m. However, the study highlighted the importance of considering the recoil of each rifle and its potential impact on the soldier's shoulder tissues. The study's findings suggest that there may be difficulties in achieving a high level of accuracy when firing 6-8 bullets in burst mode to hit a 1000 sq. cm area, which raises concerns about the feasibility of using this firing method. Overall, the study provided valuable insights into the feasibility and challenges associated with the body armour design and burst fire mode of modern rifles for military personnel.

1. INTRODUCTION

Limited information is available on various firing modes available in different rifles and their applications. The firing mode of a rifle determines the number of bullets that can be fired with each pull of the trigger and can have a significant impact on the accuracy and effectiveness of the weapon. There are several different firing modes available in rifles, including [1],

(i) Single shot: A single-shot rifle allows for precise aiming and can be useful for hunting or target shooting where accuracy is paramount.
(ii) Bolt action: A bolt action rifle is a type of single-shot rifle that requires the shooter to manually cycle the bolt to eject the spent cartridge and load a new round. This firing mode is reliable and accurate and is commonly used in precision shooting competitions.
(iii) Semi-automatic: A semi-automatic rifle can fire multiple rounds with a single trigger pull, which can be useful in situations where a rapid fire is necessary, such as in combat or self-defense. However, the rate of fire may make it less accurate compared to a single shot or bolt action rifle.
(iv) Full automatic: A fully automatic rifle can continuously fire rounds as long as the trigger is held down. This firing mode is primarily used in military and law enforcement contexts.

Overall, the importance of a specific firing mode in a rifle depends on the intended use of the firearm. For example, a hunter may prioritize accuracy and choose a single-shot or bolt action rifle, while a soldier may prioritize rapid fire and choose a semi-automatic or fully automatic rifle. Owing to the excessive consumption of bullets in fully automatic mode, a limited number of bullets are fired in automatic mode that serves better and in general the same is termed as burst fire.

Burst fire is a shooting technique that involves firing a predetermined number of rounds in quick succession. Three-bullet burst fire is a specific type of burst fire that involves firing three rounds with a single pull of the trigger. This technique is commonly used with rifles and is a popular choice for both military and law enforcement personnel. The primary factors in favour of 3-bullet burst fire using a rifle are,

(i) Precision and Control: One of the primary advantages of using three-bullet burst fire with a rifle is that it allows for a high degree of precision and control. By firing only three rounds at a time, the shooter can maintain accuracy while minimizing recoil and operating the weapon.

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(ii) Efficient Use of Ammunition: Another advantage of using three-bullet burst fire is that it allows for efficient use of ammunition. Rather than expending a large number of rounds in a short amount of time, the shooter can conserve ammunition by firing in controlled bursts.

(iii) Training and Technique: Using a three-bullet burst fire effectively requires a high degree of training and technique. It needs the shooter to be able to quickly and accurately fire three rounds in succession, while also maintaining control of the weapon. As such, it is a technique that is typically reserved for experienced shooters who have received specialized training.

The advantages of using 3-bullet burst fire mode over a single bullet and fully automatic fire are established yet the feasibility of all the bullets hitting every time within the target area needs further investigation. The 3-bullet burst fire also has some limitations. For instance, it can be less effective in engaging multiple targets or engaging targets at longer ranges, as it may not provide enough rounds to take down a target. Moreover, the limited number of rounds in each burst can also minimize the need for reloading, which can be an advantage in situations where time is of the essence. The recoil of a rifle in burst mode is yet another area of major concern. Firing a rifle in burst mode creates a higher recoil than firing a single shot and this can cause damage to the shoulder tissues of the shooter. The impact of the recoil on the soldier's shoulder can vary depending on the rifle and the size of the bullet used. It is important to consider the recoil and its impact on the shooter when selecting a rifle for burst fire mode [2]. While it has its advantages and limitations, it is important to consider the context and specific requirements of each engagement when evaluating the effectiveness of burst fire.

Body Protective Jackets (BPJs) are typically designed with an area ranging from 735 to 1000 sq cm in accordance with standards set by organizations like the National Institute of Justice (NIJ) or the Bureau of Indian Standards (BIS) [3][4]. Generally, a BPJ encounters a single shot at a time. However, in burst fire scenarios where multiple bullets are fired within a short span of less than a second, there is a possibility that three bullets may hit the BPJ. This raises concerns about the effectiveness of the current BPJ design in adequately protecting against burst fire incidents. Consequently, there may be a need for improvements in BPJ design to enhance their ability to withstand and mitigate the impact of multiple bullets hitting within such a short timeframe.

Despite its widespread use, there is a lack of understanding of the mechanics of 3-bullet burst fire, and its potential advantages and limitations compared to other firing techniques. Also, in case the person is hit with one or more bullets with or without a suitable bullet-resistant jacket fired from a given rifle will suffer how much trauma/injury needs to be investigated. As understanding the level of trauma and injury caused by different bullet impacts is crucial for assessing the effectiveness of protective gear and developing improved strategies for soldier protection. Expanding research in this area, will enhance the understanding of the physiological effects caused by bullet impacts and ultimately enhance the survivability and well-being of individuals in combat situations.

Accordingly, the first objective of the present study is to establish the feasibility of 3-bullets hitting the target when fired using different rifle types with their respective ammunition. For the study purpose, the weapons used were SMC (Sub Machine Gun), INSAS (Indian Small Arms System), AK-47 and a newly inducted weapon by the Indian forces SIG Sauer 716 (Table 1). The ammunition used by each of the weapons were 9 x 19mm FMJ/Pb, 5.56 x 45mm FMJ/(SI+Pb), 7.62 x 39 mm HSC (Hard Steel Core) and 7.62 x 51mm FMJ/Pb (M80 NATO Ball), all the bullets were supplied by two of the primary Ordnance Factories of India (Table 2). After the burst impact, the area covered by 3 bullets is vital that will depend on several factors, including the caliber, velocity, and type of the bullets, as well as the distance between the bullets and the target. Also, the factors of stability, accuracy, health condition and ability to bear rifle recoil of personnel using the weapon will significantly affect the accuracy of burst fire. On the basis of the area under the impact, impact energy density was estimated, which will help in better designing the bullet-resistant panels. Also, the possibility of organ or muscle damage can be enumerated on the basis of impact energy density.

2. METHOD

Generally, in shooting ranges accuracy of bullet shots is vital. Accordingly, the majority of soldiers are trained to precisely fire a single round. However, when it comes to automatic firing or 3-bullet bursts, a slight reduction in accuracy is inevitable. Accordingly, to make all the soldiers comfortable with the experimentation scheme, a minimum of 10 sets of 3-bullet fires were conducted as a practice set. INSAS and AK-47 were the main experimentation weapon and a limited number of tests were also conducted using SMC and SIG Sauer 716. The total number of 3-bullet burst fire experiments conducted using each bullet and weapon type is presented in Table 1. As the recoil produced by a 9x19mm FMJ/Pb bullet when fired using SMC is presumably the lowest compared to any other firearm, the accuracy was highest and

accordingly a lesser number of experiments were conducted for this case. The primary study focus was on rifles and accordingly, 30 sets of experiments were conducted with INSAS and AK-47 rifles. Owing to the highest recoil of SIG Sauer leading to significant variation in the hit locations, the experimentation was limited to 10 sets.

Table 1. Number of 3-bullet burst experimentations conducted using each weapon type

S. No.	Bullet type	Weapon	Number of 3-bullet burst fire tests conducted
1.	9 x 19mm FMJ/Pb	SMC	5
2.	5.56 x 45mm FMJ/(SI+Pb)	INSAS	30
3.	7.62 x 39mm HSC	AK-47	30
4.	7.62 x 51mm M80 Ball	SIG Sauer	10

The experimental scheme depicted in Figure 1 involves firing a bullet at a target from a distance of 10 meters. To measure the velocity of a bullet, a ballistic chronograph is placed 5 meters before the target. A ballistic chronograph is a device that measures the velocity of a bullet by detecting the interruption of two light beams as the bullet passes through them. By measuring the time, it takes for the bullet to pass through the light beams, the chronograph can calculate the bullet's velocity and is used for single shot validation purposes only.

In addition to the chronograph, a high-speed camera is placed suitably to capture the ballistic event for further analysis. The camera is set up to record the impact of the bullets on the target and to provide a detailed view of the bullet's trajectory into the target and impact dynamics. The frame rate of the high-speed camera was set at 10,000 fps to capture the ballistic event. The high-speed imaging data can be used to analyze the performance of the bullet, the rifle and bullet resistant panel, as well as to identify any potential issues or areas for improvement. Overall, this experimental setup is designed to provide detailed information about the performance of the rifle and bullets, which can be used to improve accuracy and optimize the design of the personal body armour, apart from serving as feedback to the person using the rifle.

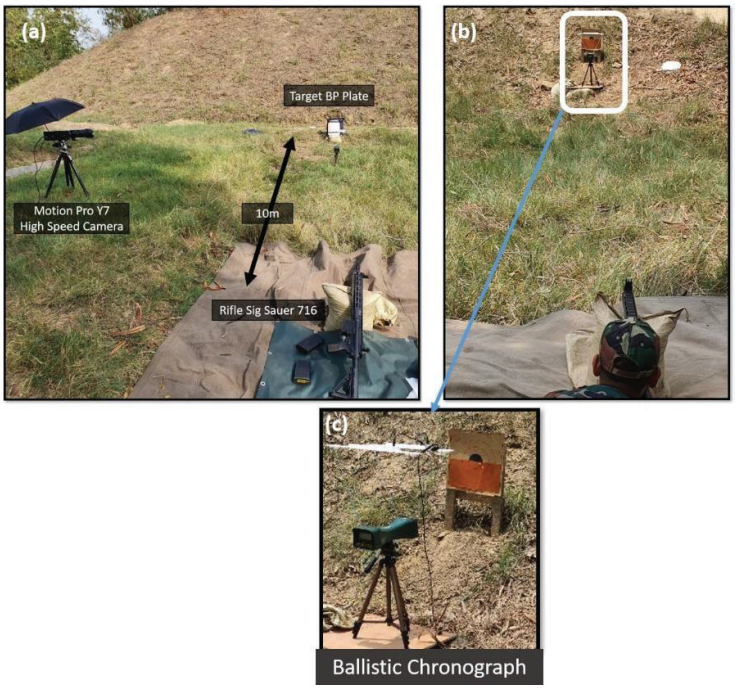

Figure 1. Set-up used to conduct the 3-bullet burst fire (a) complete set-up with a high-speed camera, (b) Soldier firing in burst mode, and (c) ballistic chronograph

The shooters' level of experience with the various weapons can indeed play a determining role in the intershot distance. In the case of the AK-47, the first three targets of the 3-bullet burst were fired by a soldier with 10 years of experience, while the remaining 27 targets were fired by a soldier with 28 years

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of experience. As for the INSAS rifle, the first nine targets were fired by a soldier with 28 years of experience, and the remaining 21 targets were fired by a soldier with 29 years of experience.

Table 2 presents the specifications of different bullet types used and the energies associated with the impact of each bullet type. This fact is noteworthy that not all bullets will attain equal speeds and there will always be a minor variation in the bullet mass within the permitted range. Accordingly, the kinetic energy (KE) was calculated on the basis of an average of experimental results.

Table 2. Bullet types and specifications used for the study

S. No.	Bullet	Velocity (m/s)	Mass (g)	K.E. (J)
1.	9 x 19mm FMJ/Pb	430 ± 15	7.5± 0.05	740
2.	5.56 x 45mm FMJ/(SI+Pb)	890 ± 15	4.2± 0.05	1500
3.	7.62 x 39 mm FMJ/HSC	700 ± 15	8± 0.1	2016
4.	7.62 x 51 mm FMJ/Pb	840 ± 15	9.5 ± 0.1	3350

3. RESULTS AND DISCUSSION

3-bullet burst fire testing was done using four different types of weapons with the respective bullet types. The primary focus was on the results of INSAS and AK-47. In order to examine the influence of soldiers' posture on firing accuracy, two distinct firing positions were employed during the experimentation process(i) prone position giving complete stability to the human body and a sandbag to support the rifle barrel, and (ii) standing in a trench with a foot resting against a wall and rifle barrel on a sandbag as shown Figure 2. Initial 12 experiments were conducted in the prone position and the remaining 18 experiments were conducted with soldiers in the trench. Apart from the main study focusing on INSAS and AK-47 rifles, two other studies were conducted using SMC and SIG Sauer 716.

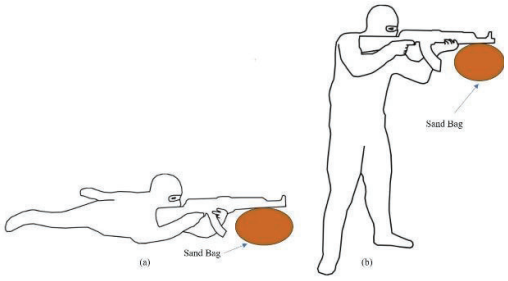

Figure 2. Firing positions used for 3 bullets burst fire experimentation (a) prone position, and (b) standing position

3.1 Sub-Machine Gun

A small study was conducted on firing 3 bullets using a Sub Machine Gun (SMC) with 9x19mm bullets in five experiments. For this experiment set, actual soft armour panels (SAP) were used instead of paper targets.

The results showed that the intershot distance with SMC was always less than 100mm and in the range of 20-100mm. However, due to the limited data on deformable SAPs, no significant conclusions could be drawn. It was observed that owing to the lowest bullet energy and lowest recoil, all the SMC bullets could comfortably hit within the target area. However, the study proves that SMC with 9x19mm bullets is a reliable option for shooting tasks where accuracy is paramount within a short distance.

3.2 INSAS Rifle

Figure 3 presents the experimental data of intershot distances of a 3-bullet burst fire when 5.56x45mm bullets were fired using an INSAS rifle. Out of 30 burst fire rounds, 29 times all the bullets successfully hit within the (paper) target area of 350 x 300 mm^2. Experiment number 25 was a rogue one wherein the third bullet couldn't hit within the target area. Apart from that another interesting fact observed was that

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in three of the experiments, one after the other bullet hit was in a straight-line path. Figure 3(a-c), presents the intershot distances between the 1-2, 2-3 and 3-1 bullets on a paper target. It's noteworthy that intershot distance between shot numbers 1-2 could never attain distances less than 25mm. Also, the majority of intershot distance for 1-2 bullets were in the range of 25-100mm. For four specific cases, the intershot distance was recorded as higher than 100mm. Figure 3(b) depicts that less than 25mm intershot distance happens but it's a relatively less common phenomenon. Also, intershot distance of higher than 100mm is relatively less common. By the time the third bullet comes into action, the shoulder of the human operating the rifle had already experienced two recoil jerks. Accordingly, the third bullet was expected to hit far from the first bullet location and the same was also experimentally confirmed in Figure 3(c). Also, the number of intershot distances well above 100mm increased significantly. On comparing Figure 1(a) and 1(c), it was observed that intershot distances for shot 1-2 were closer to 25mm mark, whereas intershot distances for shot 3-1 were close to 100 mm mark for the majority of cases. Figure 3(d) presents combined results of intershot distances and it can be claimed on the basis of the figure that the given security personnel were trained enough to fire the majority of 5.56x45mm bullets using INSAS rifle in the range of 25-100mm.

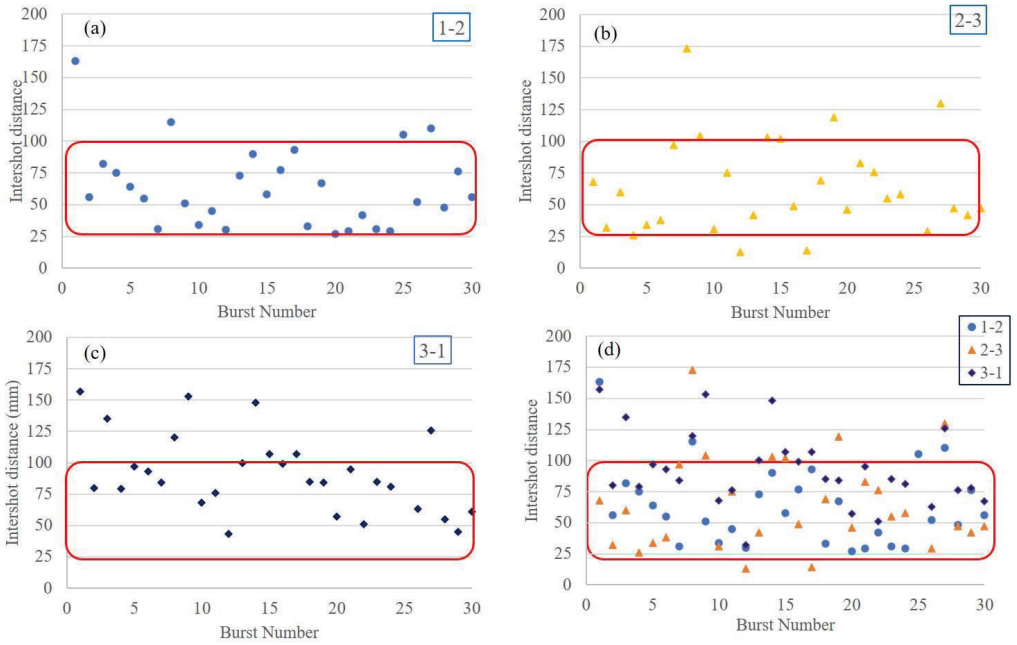

Figure 3. Intershot distances for 3-bullet burst round fired from a distance of 10m for INSAS Rifle (a) distance between shot 1-2, (b) distance between shot 2-3, (c) distance between shot 3-1, and (d) combined result of 3-bullet burst.

3.3 AK-47 Rifle

Figure 4 presents intershot distance data of 7.62x39mm bullets when fired in 3-bullet burst mode using an AK-47 rifle. Out of 30 burst fire rounds, 27 times all the bullets successfully hit within the (paper) target area of 350 x 300 mm^2. For experiment numbers 12, 19 and 28 the third bullet couldn't hit the target area. Apart from that it was observed that in five of the experiments, one after the other bullet hit was in a straight-line path. The average spread of the AK-47 rifle was measured to be 62.4 mm, 48.5 mm, and 88.7 mm between shot number 1-2, 2-3, and 3-1, respectively. On the other hand, for the INSAS rifle, the average spread was recorded as 62.2 mm, 64.2 mm, and 92.5 mm between shot number 1-2, 2-3, and 3-1, respectively. A rare instance of intershot distance for shot numbers 1-2 was noted as less than 25mm, which was not the case with INSAS rifle. Interestingly, the number of intershot distances on higher side (above 100mm) was also higher for AK-47. Intershot distance data for shot numbers 2-3 as depicted in Figure 3(b) was an interesting finding, as the majority of data points were within the range of 25-100mm. Similar to INSAS, the intershot distances for between shot 3-1 raised from 25-50mm to close to 75-100mm (Figure 4(c)). Overall, in this case also the majority of intershot distances were in the range of 25-100mm (Figure 4(d)).

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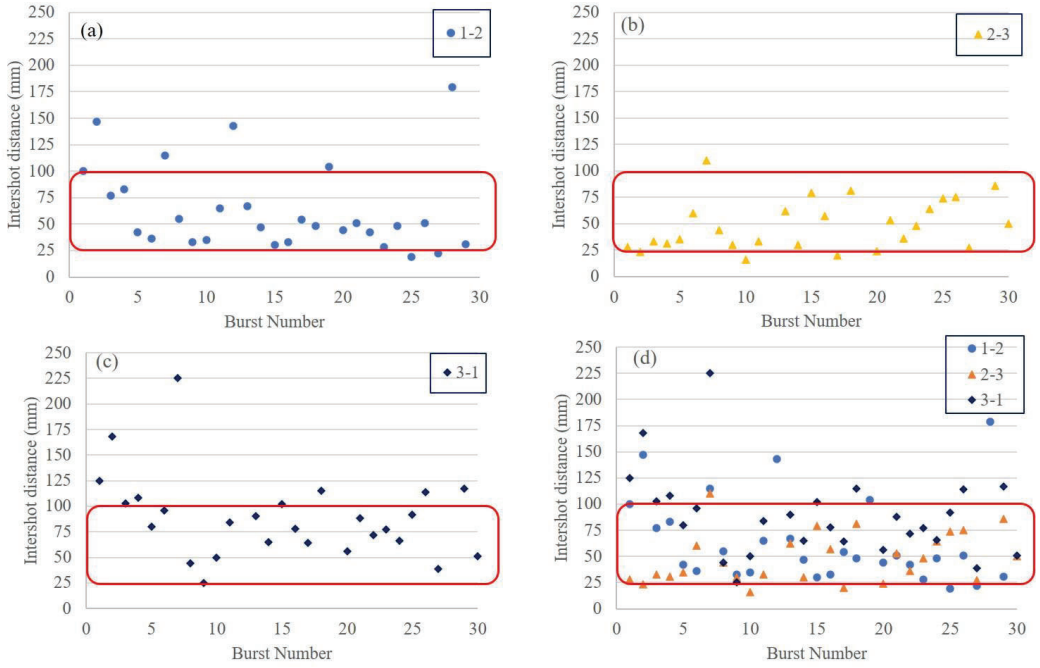

Figure 4. Intershot distances for 3-bullet burst round for AK-47 Rifle

3.4 Energy density

In real life scenario, perforation of bullet resistant panel will lead to a bullet hitting a person, however, even if 3-bullets of a burst fire are stopped by a suitable bullet-resistant panel, then the total impact energy of 3 bullets hit within a small time of ~0.3 seconds has to be borne by the localized human body area. The exact site of this local area will vary for each case and which vital human body organ is at the back of the panel can never be predicted. To evaluate the impact energy transmitted to the human/target area, the intershot distance data was used to create suitable triangles wherever feasible. The area of triangles for 3 bullet burst fire for INSAS and AK-47 are presented in Figure 5 (a, c). Knowing the average impact kinetic energy (KE) per bullet shot, the energy density for both rifles for all the experiments was established and is presented in Figure 5 (b, d). The higher intershot distances along with the lower total KE in the case of INSAS rifle led to relatively lower total energy imparted to the unit area in Joules per square mm. For AK-47, a relatively lesser impact area with higher bullet KE resulted in higher energy densities. The proposed energy density function can serve the purpose of evaluating the possibility of damage applicable to human muscles, vital organs and bones. Table 3 presents the average area of triangles and energy densities generated due to 3 bullet burst fires. As expected, the average energy to be borne by a target is higher for 3 bullets fired from an AK-47 rifle. This indicates that a person even if saved due to the presence of a suitable bullet-resistant panel, will experience a higher impact and the possibility of organ/bone damage due to behind armour blunt trauma (BABT) will be higher in case of a hit by burst fire of three bullets by a AK-47 rifle.

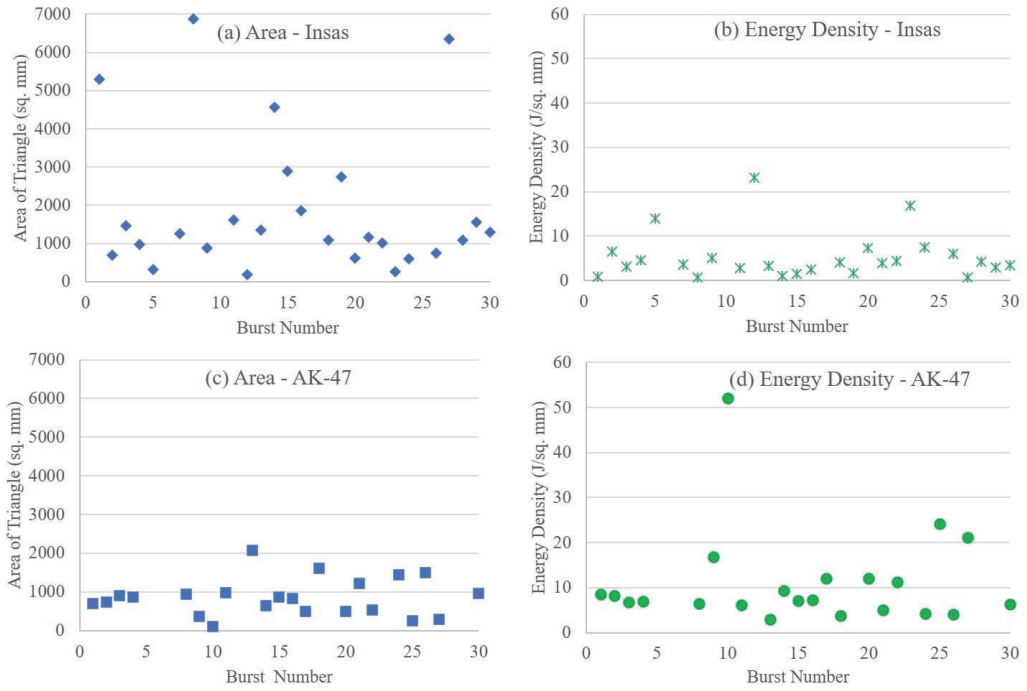

Figure 5. Comparison of triangle area and energy density for 3-bullet burst fire using INSAS and AK-47 rifle

Table 3. Average triangle areas and energy densities [5][6]

Rifle type	Average Area of Triangle (sq. mm)	Average Energy Density (J/sq. mm)	Recoil
INSAS	1943	4.5	4.43
AK-47	856	11	9.35

3.5 Post-Impact Analysis

Figure 6 shows the experimental results of firing 3 bullets in burst mode using INSAS and AK-47 rifles. In Figure 6(a), it is shown that when firing with an INSAS rifle, the bullets can hit the target in a triangle shape. The leg lengths of the triangle varied in 26 experiments. Figure 6(b) shows that it is possible for all three bullets to hit in a straight line also, but this only occurred in 10% of the total cases. Figure 6(c) depicts the rare phenomenon where the third bullet did not hit the target area.

Figures 6(d-f) show similar experimental findings for burst firing 3 bullets using an AK-47 rifle. The results indicate that, compared to the INSAS rifle, the AK-47 rifle had more variation in the results. In 5 out of 30 experiments, the bullets hit the target in a straight line, and in 10% of the cases, the third bullet did not hit the target area.

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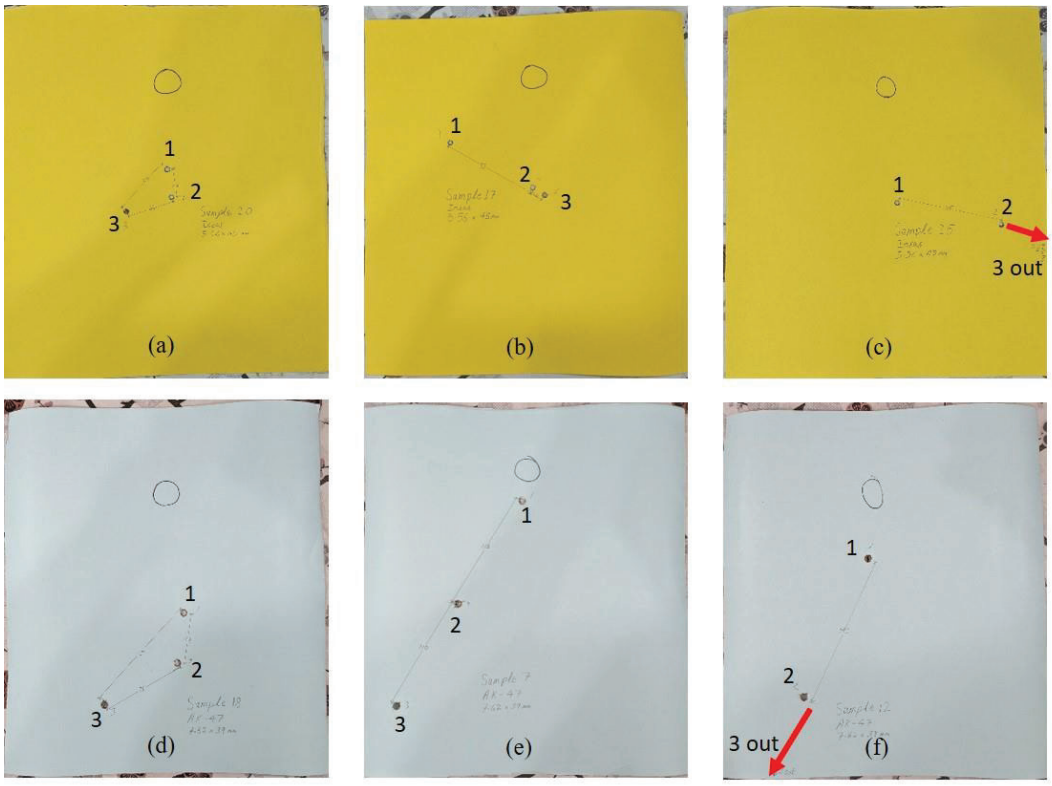

Figure 6. Sample INSAS rifle fired targets (a) 3-bullet burst inside the target forming triangle, (b) 3-bullet burst in-line, (c) first, second bullet inside and third bullet outside the target area, and sample AK-47 fired targets (d) 3-bullet burst inside the target forming triangle, (e) 3-bullet burst in-line, (f) first, second bullet inside and third bullet outside the target area.

3.6 SIG Sauer 716

A small study was conducted on firing 3 bullets using a SIG Sauer 716 with 7.62x51mm bullets in ten experiments. For this experiment set hard armour panel (HAP) was used along with the paper targets. The SIG Sauer 716 is a relatively new weapon recently introduced into the Indian army. In the experimental range of bullet types, 7.62x51mm is the largest-sized bullet. A total of ten 3-bullet burst fire tests were conducted, five on hard armour panels (HAP) and five on paper target. The results showed that, generally, only two out of the three bullets hit within the target area of 1000 sq. cm. Out of 30 burst fire rounds, 21 bullets successfully hit within the target area of 350 x 300 mm^2. Only 5 pair of bullets had intershot distances less than 100mm, while the rest of the 16 bullets had intershot distances in the range of 100-275mm.

Figure 7 shows the damage caused to the soldier's shoulder tissues due to the recoil of the SIG Sauer 716 firing 7.62x51mm bullets. Though 10ms as reported in the literature [2] is a small time yet within this small time when peak recoil of a rifle occurs, it creates difficulty in maintaining the aim of a soldier. The reddening of the shoulder portion that supports the rifle is visible in the figure, indicating the impact of the recoil on the soldier's shoulder. This, in turn, can result in a decrease in the accuracy of hits after a few rounds of bursts. It's worth noting that while both the INSAS and AK-47 have enough recoil to affect the accuracy of a soldier's aim, they don't seem to leave a notable mark on the shoulder. Therefore, it is important to take measures to reduce the impact of recoil on soldiers shoulder to maintain the accuracy and effectiveness of their shots.

Figure 7. Effect of SIG Sauer 716 rifle recoil on the soldier's shoulder after firing over 50 bullets of 7.62 x 51mm M80 NATO Ball

Figure 8 depict the aftermath of firing two sets of three bullet bursts of 7.62x51mm using SIG Sauer 716 on a hybrid Hard Armour Panel (HAP), displaying the resulting damage on the front, rear, and side of the panel, as well as how the panel covers vital body organs. Figure 8 (c) clearly illustrates the back-face deformation caused by the impact, which has the potential to cause severe damage to any vital body organ it comes into contact with. It's important to note that the back-face deformation shown in this case is the result of an edge shot, where the distance from the side edge was less than 51mm. However, in real-world scenarios, it may not be feasible to maintain such precise dimensions during a firearm attack, which the standards like NIJ 0101.06 or BIS 17051:2018 talks about and leaves an open question of personal body armour safety guarantee. Under the given conditions, the need for 3-6 Armour Piercing Incendiary (API) bullets to hit a restricted 1000 sq. cm area is also a matter of concern, given the challenges highlighted in the study regarding the accuracy of firing bursts of bullets in this way.

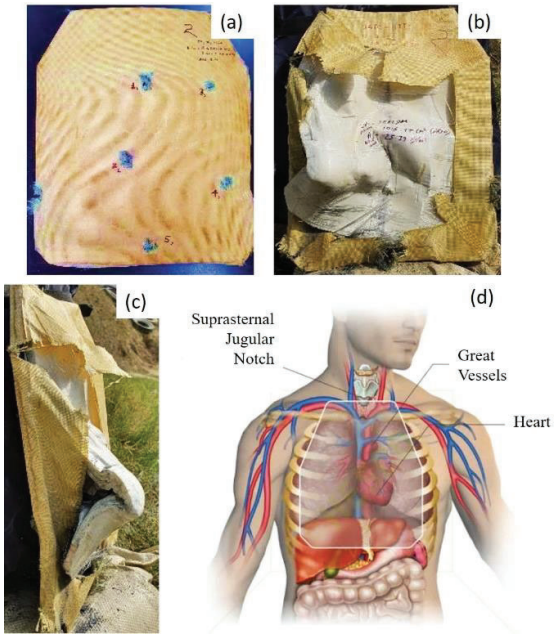

Figure 8. Images of Hard Armour Panel (HAP) after bearing two sets of 3 bullet burst (a) front, (b) rear, (c) sideview and (d) vital body organs covered by a HAP

4. CONCLUSIONS

It is important to note that firing a firearm accurately in a small area, such as 1000 sq. cm, can be challenging, especially in a burst mode. The accuracy of firing a firearm depends on various factors such as the skill level of the shooter, the type of firearm and the distance from the target.

AK-47 rifle is a more powerful weapon than the INSAS rifle. The AK-47 rifle fires a larger cartridge than the INSAS rifle, which results in more energy being transferred to the target. This increased energy can result in more damage to the target and surrounding areas leading to extensive BABT.

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It is practically not feasible to achieve an intershot distance of 25mm in burst mode of a rifle even when the firing distance is just 10m. This distance is too small to be achieved even by skilled marksmen. In fact, the experimental data presented in this study shows that the intershot distances are much larger.

The SIG Sauer 716 rifle firing 7.62x51mm bullets showed the maximum variation in shot pattern results. On the other hand, the INSAS and AK-47 rifle shows a consistent result, with intershot distances ranging from 25mm to 200mm and a higher percentage of bullets hitting within the target area in 3-bullet burst mode. This indicates that the INSAS and AK-47 may be more efficient weapon for burst fire, at least within the experimental range of rifles tested in this study. AK-47 with HSC bullets thus becomes a more lethal weapon system against any body armour.

According to the results of the experiments, it can be inferred that firing in burst mode using INSAS, AK-47, and SIG Sauger 716 rifles leads to a certain percentage of bullets not hitting within the 1000 sq. cm target area. Specifically, the percentages of missed shots were found to be 3%, 10%, and 30% for the three rifles, respectively. It's important to note that the results may vary based on factors such as the skill and training of the shooter, environmental conditions and the specific configuration of the rifle used. Therefore, it's important to conduct further studies and more experiments to validate these findings and determine the most effective body armour systems and their testing strategies for burst fire in real-world scenarios.

One open question still remains and that is the use of sniper shots 7.62x54R (AP) using a Dragunov, which only has single shot capacity, then why there is a need of qualifying 6 shots on a 1000 sq. cm armour plate to qualify as per BIS 17051:2018 or other ballistic standards to be inducted in Indian Army and other security forces globally.

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