Self-Defence Ammunition Comparison between .22, 9 mmP, .40 & .45 Projectiles

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Abstract: This paper presents a comparison of different .22, 9 mm Parabellum (9 mmP), .40 and .45 calibre ammunition. The different projectiles are analysed by performance, considering penetration depth into ballistic gel, while compared with the penetration depth after some clothing, such as a material used for jackets, are penetrated first. The velocity, kinetic energy, and kinetic energy per cross-sectional area of the projectile are analysed, to identify which calibre and projectile has the most impact force on a threat. A cost comparison of the different ammunition is shown, while an analysis is done of the cost per kinetic energy per cross sectional area, for different ammunition..

Additional keywords: Self-defence ammunition, penetration depth, projectile performance, calibre performance.

1 Introduction

The research recently conducted showed that a single layer of Kevlar had an opposite effect on hollow point projectiles, in that they penetrated deeper into ballistic gel, in comparison with the shooting directly into the ballistic gel [1]. With this result in mind, it was decided to investigate if similar results would be obtained with clothing material, which is commonly worn by people.

A misconception is that smaller calibre projectiles are less effective and should not be used for self-defence purposes [2,3], yet these sources have shown inconsistencies, where smaller calibre ammunition are requiring less rounds before incapacitation [2]. The .22 inch diameter ammunition has a small diameter in comparison to other ammunition and considered to be a "mouse gun" [2], yet the results showed that 1.38 rounds before incapacitation, was observed and to be the lowest of all ammunition (other than the shotgun rounds) [2]. Other articles indicate that .22 ammunition should not be used for self-defence due to the low penetration depth [3]. Comparison of ammunition performance in controlled research are rare, yet a comparison between a .22 and a 9 mmP projectile has been conducted to investigate the ricochet effects [4]. Based on this contradictions, further investigation is required to identify the performance of different projectiles for self-defence purposes, correlating with penetration depth, kinetic energy and the ratio of kinetic energy and cross-sectional area of the projectile.

With self-defence, according to the South African Firearm Control Act 60/2000 [5], a firearm may only be used where it is safe to be used, and for lawful purposes. Since it is the responsibility of the shooter as to where the projectile goes, and their responsibility of the loss of lives if an innocent person should be hit [6-11], it is the best interest of the firearm owner and shooter that appropriate ammunition is used. There are two points that must be taken into account. 1) The shooter does not want the projectile to go through the threat and injure another innocent person behind them, or an innocent person behind a wall, behind the threat. 2) The main purpose of the firearm is to get the threat neutralized, so the projectile must be able to give enough impact, yet penetrate the shortest possible distance, so that no person or property is injured behind the threat. The threat is to be neutralized using the least life-threatening method possible [6-11].

Publications about the small arms control, especially in South Africa, and Africa, are available in literature [12, 13]. Strict firearm control, as in South Africa with the Firearm Control Act 60/2000 [5], have been implemented due to deaths that have occurred where there is no responsibility. A firearm for self-defence purposes is required to be able to stop the threat with the maximum energy density, yet prevent the projectile to penetrate the threat the least possible distance, so as no bystanders are harmed. Research has been conducted on the wound paths with shots into ballistic gel [14], yet this research focuses more on the penetration depth into a target. Ammunition have unpredicted characteristics, which are affected by the rifling used in the firearm barrels, with the explosion of the gun powder, therefore giving more realistic ballistic results compared to gas guns [15] and weight drops [1]. Comparisons of different ammunition has been documented before, yet the comparisons have been performed by companies that support certain makes and types of ammunition, which might show biased results.

The tests are commonly not done in a controlled fashion, as the ballistic gel is able to move back substantially after being shot, which is important to consider, as seen in [16], that the target will not move in the direction of the projectile path. The analysis of the results are not always performed in a scientific manner, yet there have been research that were conducted in a scientific manner, only with use of one make of ammunition [17].

The contributions of this paper are to answer the following questions:

- Is the current belief that larger projectile is more powerful/lethal true?
- Will jacket cloth material have a similar effect on different projectiles as a layer of Kevlar would have, since most people who are shot in self—defence scenarios would be wearing some form of clothing?
- What is the shortest distance that the projectile of different ammunition, will penetrate for self-defence purpose, yet have the maximum performance?
- Does the cost of ammunition and the projectile performance correlate?

It is to be noted that the authors are not associated with the companies manufacturing the ammunition and obtained no financial gain for performing the tests. The results given

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are unbiased, and are purely as observed in the tests conducted. Due to the uncertainties of the projectiles characteristics, where it loses stability after it penetrates the ballistic gel [18], many of the tests conducted in the present study had to be repeated numerous times, for example, when the projectiles deviated out of the ballistic gel, or external interference was observed that might have an effect on the results.

2 Ballistic Gel, Jacket Material Samples, Experimental Procedures and Ammunition Used

This section explains the way the ballistic gel was manufactured, how the jacket material samples were made, the experimental setup, and the ammunition used in the tests conducted.

Unflavoured gelatine was used to make the ballistic gel. A ratio of 1 part (1.25 kg) gelatine with 4 parts (8 litres) of water was used. The solution was poured into two 5 litre containers, after which 5 drops of cinnamon essential oil was stirred into the solution, for the purpose of disinfection and the dissipation of the bubbles in the gelatine solution. After the solution was set in the fridge for 36 hours, the gelatine blocks were wrapped in cellophane wrapping. The average density of human blood, fat and muscle is 1004 kg/m^3 [19], and the density of the ballistic blocks were 996 kg/m^3. The concentration of the ballistic gel is not considered to be the factor of importance, yet the similarity of the density of a person's body is considered vital [20]. Therefore, the density of the ballistic gelatine used in the experiments in this paper were considered a better resemblance compared to the 20% concentration ballistic gel, which had a density of 1060 kg/m^3 [17] to be used in ballistic tests. A video showing the details to make the ballistic gel is available from https://www.youtube.com/watch?v=0nLWqJauFEw.

The jacket material was considered as a scenario where a person is shot while wearing clothes. Since the torso is the largest part of the target to be shot at, a person would be wearing some form of clothing, such as a jacket. The jacket material that was used for the tests consisted of two sheets of 100% cotton, cross-woven material (used for shirts), sandwiched with the commercial synthetic jacket material padding, used for windbreaker jackets. The sandwiched padding and cotton material was kept in place by sewing them together with cotton thread.

Controlled ballistic tests were conducted with different ammunition of different calibre (.22, 9 mmP, .40, and .45 projectiles). The firearms used for the tests for the correlating calibre, were an Anschutz .22 rifle, Glock 17 in a Roni carbine converting kit for the 9 mmP ammunition, Glock 24 for the .40 calibre ammunition, and a Colt 1911, 1979 government issue for the .45 calibre ammunition.

The configuration for the tests conducted, were performed according to figure 1. The ballistic gel block, and the table it was mounted on, was secured so that it does not move backwards [16], to allow it to absorb the full energy from the projectile, which was 1 m away from the chronograph.

The projectile was fired through a chronograph to measure the bullet speed as it leaves the firearm barrel. The chronograph was placed 2 meters away from the firearm muzzle, to prevent the muzzle flame to interfere with the chronograph. The ballistic gel was placed 1 meter after the chronograph, to prevent the spray of the shot ballistic gel onto the chronograph. The close proximity shot was performed, to simulate the worst case scenario of a person being shot in a possible self-defence scenario, taking into account the restrictions of the equipment used.

Figure 1 Side view of the equipment setup.

The velocities of the projectiles were averaged from ten tests conducted, with the same make of ammunition and firearm. The velocity of the projectile was considered only acceptable when the chronograph showed similar reading as identified by the ammunition manufacturer's specifications, and if the deviation was within 10% of the average. The test was performed again if the velocity deviated. The equation was used to obtain the kinetic energy of the projectile, where E is kinetic energy, m is the mass of the projectile, and v is the velocity of the projectile. A large portion of the projectile energy (as much as 50%) is transferred to the gel [21], therefore the importance to know the energy of the projectile before penetration. The shock transfer to the body, which correlates to the kinetic energy transfer, has a stopping effect on the threat.

Initially, only the ballistic gel was shot with the different ammunition, to get a baseline of penetration depth. The depth that the projectile penetrated the ballistic gel was measured and recorded. The same tests were performed with the jacket material in front of the ballistic gel. The projectile penetrated the jacket material, and the penetration depth into the ballistic gel was measured and recorded.

3 Results

The ammunition that was used in the tests, are numbered and described in table 1. The ammunition are the common types and makes being used by the majority of firearm users and sold in stores. Since this paper is comparing the effects of the 22, 9 mmP, .40 and .45 projectiles, the different makes and types of these calibre were considered. Table 1 is color-coded: the yellow highlighted section is the different .22 ammunition, cyan highlighted section is the 9 mm Parabellum (9 mmP) ammunition, green highlighted is the .40 ammunition, and the orange is the .45 ammunition. A video showing the test results and the deformation of the projectiles can be seen at https://www.youtube.com/watch?v=wBGoy-yfANI.

The drag of a projectile is proportional to the mass, velocity and the surface area of the projectile. The density of the ballistic gel also influences the drag, and therefore the penetration depth. The surface area of the projectile will increase as the cross sectional area of the projectile increases. The penetration depth of a projectile is proportional to the

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Table 1 The ammunition that were used in the experiments.

Ammunition type	Projectile weight (grains)	Velocity (m/s)	Energy (kJ)
1) Sellier and Bellot (S&B) .22 Long Rifle (LR) 36 grs High Velocity (HV)	36	412	198
2) Sellier and Bellot (S&B) .22 Long Rifle (LR) 40 grs Standard	40	344	153
3) CCI .22 Long Rifle (LR) 40 grs standard lead round	40	332	143
4) Winchester .22 Long Rifle (LR) 36 grs Hollow copper plate	36	396	182
5) Remington .22 Long Rifle (LR) Hyper Velocity 33 grs Yellow Jacket	33	424	192
6) Aguila .22 Super extra High Velocity (HV) 40 grs	40	406	214
7) TM Swartklip.22 Long Rifle (LR) 39 grs High Velocity (HV) Sabre Tip	39	417	220
8) Winchester .22 Long Rifle (LR) 40 grs Hyper Velocity	40	428	238
9) Federal .22 Long Rifle (LR) 40 grs Lightning	40	406	214
10) CCI .22 40 grs Blazer	40	398	205
11) Winchester .22 45 grs SB	45	337	165
12) CCI .22 40 grs Quiet	40	224	65
13) Sellier and Bellot (S&B) 9x19 115 grs full metal jacket	115	373	520
14) Diplopoint 9x19 124 grs full metal jacket	124	354	505
15) Federal HST 9x19 147 grs hollow point	115	327	399
16) Sellier and Bellot (S&B) 9x19 115 grs hollow point	147	347	575
17) KZN 9x19 124 grs Teflon coated	124	342	469
18) Diplopoint 9x19 85 grs Falcon hollow point	85	469	606
19) Federal 9x19 147 grs Hydra-Shok JHP	147	304	441
20) Hornady 9x19 124 grs XTP	124	248	247
21) Winchester 9x19 147 grs Ranger hollow point	147	326	505
22) Winchester 9x19 115 grs Ranger Silver Tip	115	369	508
23) PMC 9x19 124 grs Starfire SFHP	124	370	551
24) NGA 9x19 80 grs Eliminator	80	491	625
25) Lead Reloads 9x19 122 grs reloads (A)	122	328	426
26) Winchester 180 grs .40 Silvertip	180	387	873
27) Sellier and Bellot (S&B) 180 grs .40 FMJ	180	318	590
28) Starfire 180 grs .40 hollow point	180	335	656
29) Lead Reloads 170 grs .40 FMJ (B)	170	345	656
30) Starfire 230 grs .45 hollow point	230	456	1 550
31) Winchester 230 grs .45 Silvertip hollow point	230	317	750
32) PMP 230 grs .45 JHP	230	321	767
33) PMP 230 grs .45 FMJ	230	288	619

(A) 122 grs Round Nose, hardness: 9/10, Powder: 6 grs SOMCHEM 221;
(B) 175 grs Semi Wad-cutter, hardness: 9/10, Powder: 7.8 grs SOMCHEM 221

projectile mass and velocity, but inversely proportional to the cross-sectional area of the projectile [22]. The energy density is the kinetic energy per cross-sectional area of the projectile, which correlates to the stopping power or lethality of the projectile [23]. The mass of the projectiles were as per the ammunition manufacturer's specifications. This paper is focusing on ammunition required for self-defence, which need to take the following into account:

1) The penetration must be the least distance after penetrating the jacket cloth [6 - 11].
2) Due to point 1 above, hollow point ammunition is required, to prevent deep penetration, so that the projectile does not go through the target, and hurt any

bystanders, or having shrapnel injuring other people [6 – 11].

3) The maximum kinetic energy per cross sectional area, or energy density [23] is required, to allow the most impact to the threat, yet keeping into account point number 1 and number 2 above.

A comparison of the velocity, and kinetic energy of the projectiles are shown in figure 2. The ballistic gel penetration and the penetration after penetrating the jacket material, are shown in figure 3.

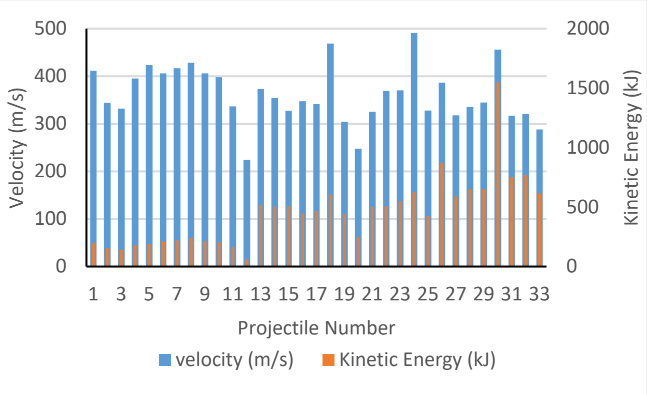

Figure 2 Comparison of the velocity, and kinetic energy for the different projectiles.

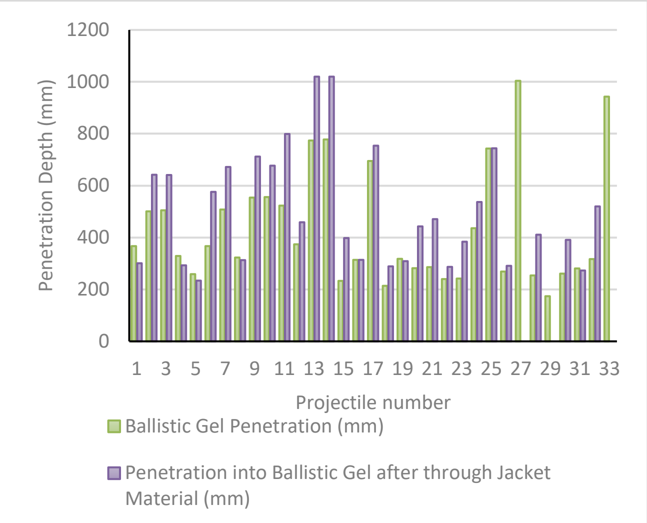

Figure 3 Comparison of the ballistic gel penetration and the penetration of the gel after going through the jacket material

The results of figure 2 and figure 3 are analysed. Projectile number 1 to projectile number 12 are the .22 ammunition. The projectiles that went further after it went through the jacketed material were projectile numbers 2, 3, 6, 7, 10, 11 and 12. Interestingly, not all the projectiles were hollow point, but some full metal jacketed (FMJ) projectiles went further. Projectile number 11 penetrated the ballistic gel even further after it went through the jacket material, in comparison to all the 9 mmP, .40 and .45 projectiles, except for projectile number 13 and number 14. Similarly, projectile number 12 had the least velocity and kinetic energy, yet the penetration after it went through the cloth was more than some of the other .22, 9 mmP, .40 and .45 projectiles. These results contradict with the misconception that the .22 projectile has a low penetration [3]. Projectile number 5 penetrated the ballistic gel the least distance of all the .22 projectiles, after it went through the jacket material.

The 9 mmP ammunition are projectiles number 13 to projectile number 25. Projectile number 13 and number 14 penetrated the ballistic gel the furthest of all the .22, 9 mmP, .40 and .45 projectiles, after they went through the jacket material. Projectile number 24 had the highest velocity and kinetic energy of all the 9 mmP projectiles. Projectile number 18 penetrated the least distance of all the 9 mmP projectiles.

Projectiles number 26 to number 29 represent the .40 ammunition. Projectile number 26 has the highest kinetic energy for the different .40 ammunition, and the highest of all the .22, 9 mmP and .40 projectiles. Projectile number 27 penetrated the ballistic gel the most in comparison to all the .22, 9 mmP, .40 and .45 projectiles. Projectile number 26 has the least penetration depth into the ballistic gel after it went through the jacket material, of the .40 projectiles tested. Projectile number 29 penetrated the ballistic gel the least, and therefore, in comparison with the other tests conducted, it might penetrate less than projectile number 26 after it went through the jacket material.

Projectile number 30 to number 33 are the .45 ammunition. Projectile number 30 had the most kinetic energy of all the .22, 9 mmP, .40 and .45 projectiles. Projectile number 31 penetrated the least distance into the ballistic gel after it went through the jacket material.

Figure 3 shows the phenomenon in that the projectiles penetrated the ballistic gel further after it penetrated the jacket material, which correlates with the experimental analysis that were observed with the penetration of the projectiles through the Kevlar material [1].

The energy density is the kinetic energy per cross-sectional area of each projectile [23], which correlates to the lethality or stopping power of the projectile, as shown in figure 4. Both terms, energy density and kinetic energy per cross-sectional area, are used in this paper.

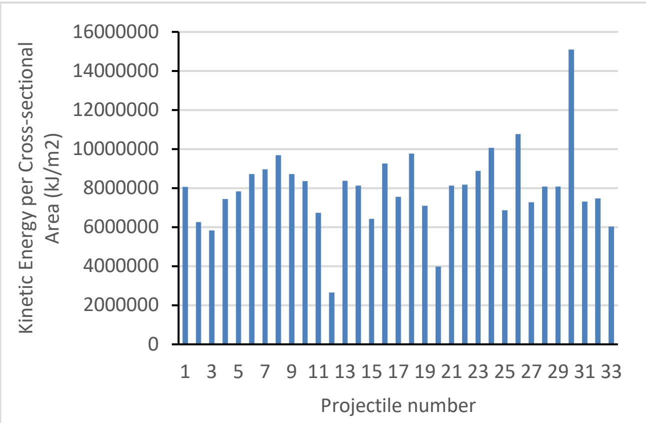

Figure 4 Kinetic energy per cross-sectional area of the different projectiles.

As seen from figure 4, projectile number 30 have the highest energy density, while projectile number 12 has the lowest. It is interesting to see that the average value is relatively constant for the majority of the ammunition. For the .22 ammunition, (projectile number 1 to number 12),

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projectile number 8 has the highest energy density. With the 9 mmP ammunition (projectile number 13 to number 25), projectile number 24 has the highest energy density, while projectile number 20 has the least. As for the .40 ammunition (projectile number 26 to number 29), projectile number 26 has the highest energy density, while projectile number 27 have the least. With the .45 ammunition (projectile number 30 to number 33), projectile number 30 has the most energy density, while projectile number 33 has the least.

As seen in figure 4, the energy density, and therefore the effectiveness of the .22 projectile, is often more than the other calibre ammunition. This observation contradicts the misconception that the smaller calibre ammunition is less effective [2].

Figure 5 shows a cost comparison of the different ammunition. The prices can change between countries and stores, yet the comparison was done at a store that places a set percentage increase on their ammunition, to allow the comparison to be performed.

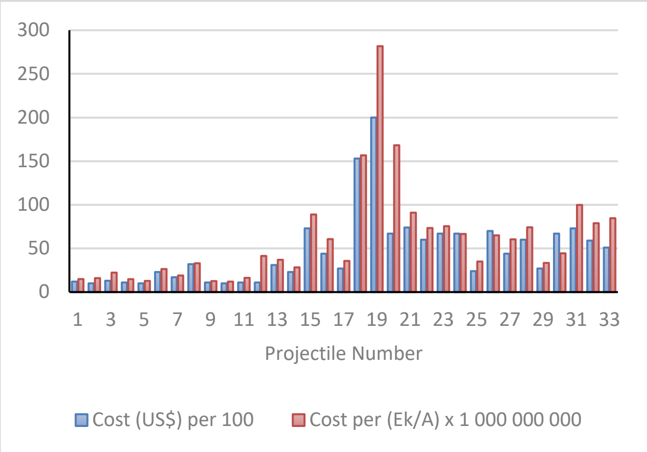

Figure 5 Ammunition cost and correlation with kinetic energy per cross-sectional area.

For self-defence purposes, the least amount of penetration is desired, yet, at the highest kinetic energy per cross sectional area (to knock a threat down) [23]. Similarly, the cost per density energy can be used to determine which ammunition have similar performance, yet at the lowest cost, to eliminate the rumour that the more expensive the ammunition is, the better it is. Therefore, cost per energy density, or cost per performance can be analysed.

Referring to figure 5, a cost per Kinetic Energy per cross sectional area comparison (Ek/A), or cost per energy density is done. The .22 ammunition (projectile number 1 to number 12), are relatively cheap, thus the small variation in the results. Projectile number 9 and number 10 show the lowest cost per energy density. Figure 3 show that projectile number 9 did penetrate the second highest into the ballistic gel, when comparing the .22 ammunition.

As for the 9 mmP ammunition (projectile number 13 to number 25), two different aspects with the cost per energy density needs to be considered, namely for the full metal and the hollow point ammunition. As for cost comparison, the cheapest full metal projectile is projectile number 14 and number 25. Projectile number 14 has the lowest cost per energy density. As for the hollow point ammunition, projectile number 16 showed the lowest cost and the lowest cost per energy density.

Looking at the .40 ammunition (projectile number 26 to number 29), the same two different aspects as with the 9 mmP are performed. Projectile number 27 has the lowest cost, and the lowest cost per energy density for the full metal ammunition. As for the hollow point projectiles, projectile number 29 is the cheapest, and has the lowest cost per energy density.

As for the .45 ammunition (projectile number 30 to number 33), projectile 33 was the only full metal projectile that was tested. As for the hollow point projectiles, even though projectile 33 has the lowest cost, projectile number 30 had the lowest cost per energy density.

4 Discussion and Conclusion

It must be noted, it is not possible to identify the best ammunition to use, as each user has specific needs. Some people, such as those in law enforcement, might have a need for projectiles to penetrate further for certain scenarios.

An experimental setup was considered, where the chronograph was placed 2 meters away from the firearm muzzle, to prevent the muzzle flame to interfere with the chronograph. The ballistic gel was placed 1 meter after the chronograph, to prevent the spray of the shot ballistic gel onto the chronograph. The close proximity shot was performed, to simulate the worst case scenario of a person being shot in a possible self-defence scenario, taking into account the restrictions of the equipment used.

The results shown in figure 4 indicates that .22 ammunition can be used for self-defence purpose, contradiction to [2]. Figure 3 shows that .22 ammunition can have a deeper penetration compared to larger calibres, contradiction to [3]. This calibre of ammunition have the advantage of being the cheapest available (as seen in figure 5), and having the least amount of recoil when fired. The 9 mmP ammunition is the most easily available, as it is one of the most common ammunition used in the world.

Using the 3 points that were introduced in the results section, which must be considered, the following order is considered in this analysis:

1) The two least penetrating, hollow point ammunition for each calibre will be considered.
2) The energy density of the ammunition in point 1 above are observed and analysed. The suggested ammunition will be therefore concluded.

From figure 3, the following calibres are considered to have the least penetration into the ballistic gel:

- For the .22 ammunition, projectile number 4 and number 5 are considered.
- For the 9 mmP ammunition, projectile number 16, number 18, number 19 and number 22 were considered. Four different ammunition is considered for this calibre, as the penetration depths are very close to each other. Projectile number 22 is rarely available, due to low stock reasons and popularity.
- For the .40 ammunition, projectile number 26 and number 28 are considered.
- For the .45 ammunition, projectile number 30, number 31 and number 32 are considered. Three different

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ammunition are considered for the .45 calibre, as projectile number 30 is rarely available.

Now correlating the above choices, referral to the energy density (figure 4) are taken into account, where the largest density energy [23] would be considered, to neutralise the threat:

- For the .22 ammunition, projectile number 5 has the highest energy density, and the least depth of penetration, between the two projectiles.
- For the 9 mmP ammunition, projectile number 16 and number 18 have more energy density, in comparison with projectile number 19 and number 22. When comparing projectile number 16 and number 18, projectile number 18 penetrated the shortest distance with a distance of 289 mm, compared to 314 mm. Yet, projectile number 16 has a lower cost per energy density between the two ammunition. A person that might want to decide between these two types of ammunition (16 and 18), will need to take into account the different variables and characteristics of these ammunition and decide depending on their needs and application.
- For the .40 ammunition, projectile number 26 has more energy density when the two ammunition are compared.
- For the .45 ammunition, projectile number 30 has the most energy density when the three ammunition are compared, yet projectile number 30 is not easily available. Projectile number 31 has the least penetration depth after travelling through the jacket material, yet a very close energy density when compared to projectile number 32. The cost per energy density of projectile number 31 is more than for projectile number 32. A person that might want to decide between these two types ammunition, will need to take into account the different variables and characteristics of each. The decision will depend on what their needs and application.

Taking into account the above analysis, a comparison between the calibres can be made, specifically between projectile number 5, number 16, number 18, number 26, number 31, and number 32. Projectile number 5 would possibly be considered the best due to the least penetration [6 – 11] into the ballistic gel after travelling through the jacket material (figure 3) and as it has the lowest cost per energy density (figure 5). A common argument is often as to which is the best between the 9 mmP, .40 and .45 calibre. The least penetration for the 9 mmP, .40 and .45 calibre are projectile number 18, number 26, and number 31 respectively. Referring to figure 4, projectile number 18 and number 26 are relatively close to each other, while projectile number 31 has the least energy density [23], which can be considered as the least effective. Comparing between projectile number 18 and number 26 with the cost per energy density in figure 5, projectile number 18 has a higher cost per energy density compared to projectile number 26. Again, the person that might want to decide between these two types ammunition, will need to take into account the different variables and characteristics to decide on their preferences, while taking into account factors such as the recoil of the firearm. From the analysis, the user will have to decide between the 9 mmP and the .40 calibre firearms and ammunition.

The contributions of this paper are concluded as the following:

- It is not always true that the larger projectile is more powerful or lethal, as this research has shown to contradict [2, 3]. The energy density, and therefore the lethality and impact of a projectile, had shown to be higher with smaller calibre ammunition compared to larger calibre ammunition. Even though projectile number 30 had the highest energy density (as shown in figure 4), the ammunition of projectile 30 is not easily available. Furthermore, with the .22 ammunition, some of the projectiles had a higher energy density compared to the 9 mmP, .40 and .45 ammunition.
- The jacket cloth material had a similar effect as the layer of Kevlar material, as observed in [1]. Six of the projectiles tests, travelled a shorter distance into the ballistic gel after penetrating the jacket material, while all the other went further.
- The shortest distance of penetration for each type of calibre ammunition has been shown. A comparison of the penetration depth into the ballistic gel (with or without the jacket material) were made, and then further analysis was conducted to identify which of these ammunition had the highest energy density. Therefore the lowest penetration [6 – 11] could be obtained, yet the highest energy density [23] was possible, therefore having the better impact to neutralise the threat.
- The cost and performance correlation was achieved by means of the cost per energy density graph (figure 5). It has been shown that often the cheaper ammunition, which has the lowest cost per energy density, penetrated the shorter required distance into the ballistic gel. There are cases where some of the cheaper ammunition were able to penetrate further into the ballistic gel, and therefore the cost of the ammunition is not a true correlation to the performance of the ammunition.

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