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Comparative Study of the Penetrability of Steel, Concrete, and Composite Glass Materials Against Small Caliber Ammunition Ballistics

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Abstract— **This research uses a literature review method that aims to compare the ballistic performance of individual weapons using small calibers, especially the 5.56 mm and 7.62 mm calibers, in terms of penetrating different types of materials. The research method included a series of firing tests using standard weapons and ammunition of the calibers under study, fired at diverse material samples, including steel, concrete, and composite glass fiber. The results showed significant differences in ballistic performance between 5.56 mm and 7.62 mm caliber weapons when penetrating these materials. The 5.56 mm caliber tends to excel at penetrating non-metallic materials such as concrete and composite glass fiber, while the 7.62 mm caliber is more effective at penetrating metallic materials such as steel. Additional analysis revealed that factors such as projectile kinetic energy, bullet deformation, and target material strength play an important role in determining the relative ballistic performance of the two weapon calibers. These findings provide valuable insights for weapon designers and military personnel to select the caliber that best suits the combat situation and target at hand.**

Keywords— Material; Penetration; Ballistics; Small Caliber; Ammunition

I. Introduction

Research into the ballistic performance of small-caliber personal weapons is a topic of great depth and relevance in the military and security context. The 5.56 mm and 7.62 mm calibers are the focus of this research due to their popularity and wide use in the modern battlefield. In the current issue of the Russia-Ukraine war, sniper rifles such as the SVD or Dragunov with a caliber of 7.62 mm are used by Russian troops to shoot from a long distance with high accuracy and great destructive power. Then the AK-74 assault rifle, which has considerable popularity among Russian troops and pro-Russian armed groups in Ukraine, originally used 5.45 mm caliber ammunition, but the AK-74 can be modified to use 5.56 mm NATO caliber ammunition. The difference in ballistic characteristics between these two calibers has been the subject of a long debate, with crucial questions about their penetration capabilities against various materials that may be encountered in the field. Therefore, the aim of this study is to provide a deeper understanding of the performance of weapons with these two calibers in penetrating different materials (Zvîncu et al., 2021).

The importance of this research also lies in its influence on weapon design strategies and military tactics. By understanding the differences in ballistic performance between the 5.56 mm and 7.62 mm calibers in the context of diverse material penetration, it can improve the effective use of these weapons in various combat situations. The findings from this research can also make important contributions in the development of new weapons or the modification of existing weapons to improve effectiveness and responsiveness on the battlefield. In addition, this study will highlight the importance of key factors such as projectile kinetic energy, bullet deformation, and target material resistance in determining the relative ballistic performance of the two weapon calibers. With a better understanding of the mechanisms behind this penetration process, we can better understand the strengths and weaknesses of each caliber, thus enabling more efficient and effective use in the dynamic combat of the modern era (Davis et al., 2021).

II. Research Methods

This research uses qualitative research methods with Systematic Literature Review (SLR) which are steps to investigate, evaluate, and analyze all findings around the research topic to answer predetermined research questions (Thomé et al., 2016). The SLR method is carried out systematically by following stages and protocols to avoid bias and subjective understanding from researchers (Xiao & Watson, 2019). The objectives of this study are to determine the ballistic performance of small caliber ammunition, specifically 5.56 mm and 7.62 mm individual weapons, in the context of material penetration, identify patterns and trends that emerge in the comparison of ballistic performance between 5.56 mm and 7.62 mm individual weapons, and evaluate the differences in penetration capability between 5.56 mm and 7.62 mm small caliber ammunition against different types of materials. In this study, there were evaluation standards consisting of inclusion and exclusion criteria. Inclusion criteria that must be met include: 1) scientific articles written in English (international journals), 2) literature sources consisting of scientific articles or conference proceedings, 3) publications originating from reputable international journals, 4) works published between 1994 and 2024 (within the past 30 years), 5) research using primary data, 6) discussion of small caliber personal weapons, and 7) research that applies ballistic performance. On the other hand, the exclusion criteria included: 1) scientific papers that are only abstracts, 2) articles published on platforms such as Blogspot, Wikipedia, or social media, and 3) publications that have a cross-section design (Linnenluecke et al., 2020).

By using SLR, data from hundreds of literatures can be accessed quickly without having to read everything. Then a PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) analysis is performed to provide a structured framework to organize the process of searching, selecting, evaluating, and synthesizing relevant literature as in figure 1 (Moher, D., Liberati, A., Tetzlaff, J., & Altman, 2010). The next step involves evaluating the quality of the article to assess whether the scientific article meets the minimum criteria that have been set. In this study, we used the Standards for Reporting Qualitative Research (SRQR) evaluation tool which consists of 21 quality evaluation components. The researcher then set a minimum threshold of 10 components for the article to be included as a literature source in this study (O'Brien et al., 2014). Of the 16 articles evaluated, 12 articles met the minimum threshold set. Meanwhile, 4 other articles did not meet the same criteria, resulting in a collection of articles as listed in table 1.

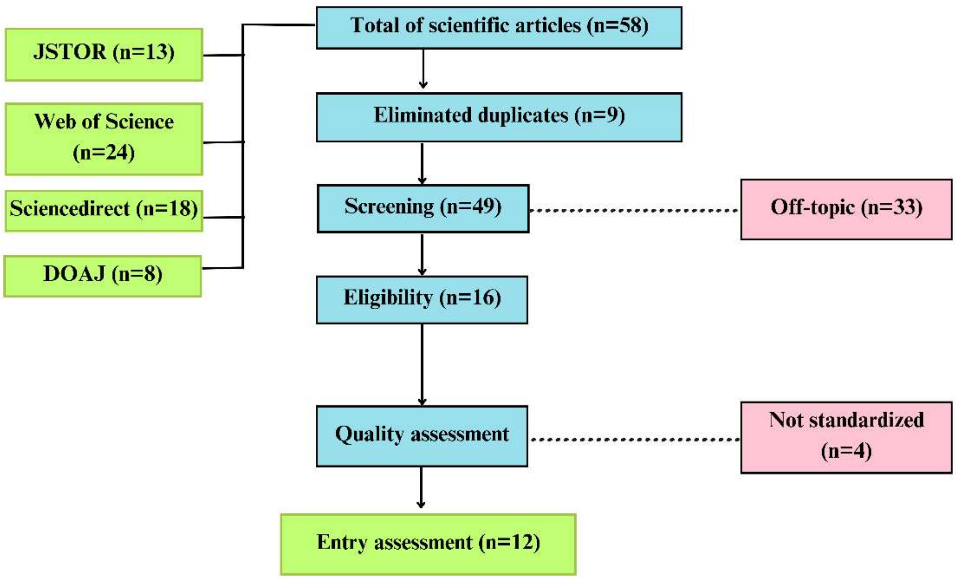

Figure 1. PRISMA diagram

III. Results and Discussion

The research results of a systematic literature review (SLR) focused on a comparative study of the ballistic performance of small caliber ammunition in the penetration of different materials, by reviewing individual weapons of 5.56 mm and 7.62 mm caliber, as in the literature in the following table:

Table 1. Relevant research on ballistic performance of small caliber ammunition against material penetration

No	Researcher (Year)	Object	Ballistic	Research Result
1.	Roland Stoughton, et al (1997)	Shock waves	External	Wavefront distortion and amplitude variations were quantified over shock propagation distances between 3-55 m (Stoughton, 1997).
2.	Rhestu Pradhipta Jati, et al (2015)	Speed, pressure, and accuracy	External	The standard specification of 7.62 mm ammunition is a minimum speed of 837 m/s, pressure of 324 MPa and accuracy of the farthest distance of 14 cm, while 5.56 mm ammunition is a minimum speed of 915 m/s, pressure of 412 MPa and accuracy of the farthest distance of 14 cm (Jati & Ore, 2022)
3.	Neculai-Daniel Zvîncu, et al (2018)	Speed and pressure	External	Velocity and pressure are measured using piezoelectric pressure sensors and Doppler radar for velocity (Zvîncu et al., 2021).
4.	Beat Vogelsanger, et al (2011)	Pressure	Internal	The peak pressure is mainly determined by the concentration of DBP in the outer 20-40 µm of the grain, and that the specified amount of DBP diffusion determined can result in an increase in peak pressure by 60-100 Mpa (Beat Vogelsanger, Bruno Ossola, Ulrich Schädeli & Ryf, 2001).
5.	L. Jedlicka, et al (2012)	Kinetic energy	External	For practical evaluation of each cartridge and its use against moving targets, the flight time to target range t30 is important. Heavier projectiles have longer flight times and in this case exceed 0.14 seconds (Jedlicka et al., 2012).
6.	Dyckmans, et al (2003)	Ballistics soap	Terminal	Soap and gelatin are materials commonly used to simulate soft human body tissue in wound ballistics experiments. These materials are considered as tools to compare the effectiveness of different projectiles (Dyckmans et al., 2003).
7.	Hui Xu, et al (2023)	Dynamic engraving process	Terminal	Compared with lead fillers, aluminum filler projectiles will cause a slight increase in maximum chamber pressure and a slight decrease in projectile muzzle velocity, an increase in sliding friction force and a decrease in maximum deformation force (Xu et al., 2023).
8.	Zvîncu, et al (2021)	Shooting range	External	Using the right tools and software, the trajectory of the projectile can be calculated if the given values are correct (mass, diameter, initial angle, initial velocity). The created tool has different weapon-ammunition specifications and loaded initial condition parameters that can be combined with existing drag laws known in ballistics (Siacci's law, 1930 law or 1943 law) to describe the movement of the projectile in the atmosphere (Zvîncu et al., 2021).
9.	Mark G. Stewart, et al (2020)	Variability and fragility	Terminal	This perforation fragility analysis considers the random variability of impact velocity, bullet mass, plate thickness, plate hardness, and model error. Such probabilistic analysis enables reliability-based design, where, for example, the

				plate thickness with 95% reliability (i.e., only 1 in 20 shots will penetrate the wall) can be estimated by probabilistically knowing the perforation distribution. Therefore, it was found that the thickness of the slab to ensure a low probability of 5% perforation needs to be 11e15% thicker than that required to have a 50/50 chance of perforation for mild steel slabs. The plate needs to be 20e30% thicker if the probability of perforation is reduced to zero (Stewart & Netherton, 2020).
10.	Ritter, et al (2021)	Burning Rate	Internal	Results from the experiments showed that both propellants functioned well. The data showed some minor differences between the two types, especially with regard to their burn rates, but the values were within nominal tolerances. Particle size seems to affect the burn rate, where larger particles have a tendency to burn faster. This is most likely a result of the deterrent process and the higher base grain to deterrent ratio when compared to smaller particle sizes (Ritter et al., 2021).
11.	Brad Gregory Davis, et al (2021)	Ballistic penetration risk evaluation	Terminal	The Alekseevskii-Tate model was found to provide an accurate estimate of penetration depth when compared to experimental and numerical results at ordnance velocities and the estimated probability of failure was on the order of 1x10-5 (Davis et al., 2021).
12	Abo El Amaim, et al (2017)	Ballistic penetration	Terminal	Polyurethane rubber which has good impact properties provides acceptable results with Kevlar and does not adversely affect its ductility. The armor produced from the composite (multi-layered Kevlar with polyurethane resin) is very light, very thin, reducing the number of layers and the cost of the armor. In addition, it can defeat small calibers in protection level IIIA according to NIJ standards (Abo El Amaim et al., 2017).

The United Nation (UN) definition of small arms and light weapons distinguishes between small arms and light weapons. Small arms are revolvers, self-loading pistols, carbines, assault rifles, machine pistols, and light machine guns (individual weapons) (Zvîncu et al., 2021). Small arms have a caliber (internal diameter of the barrel) of less than 12.7 mm. Light weapons are heavy machine guns, grenade launchers, air defense and portable tank missiles, rifles without bullets, portable rocket launchers, and mortars up to 100 mm caliber (Grand-Clément & Kondor, 2022). The 5.56mm small caliber ammunition is a type of ammunition widely used in various firearms, including assault rifles such as the M16 and variants of the AR-15, as well as submachine guns such as the M249 SAW. It is also often used in civilian weapons such as the AR-15 semi-automatic rifle. 5.56 mm ammunition has distinctive dimensions, with a projectile diameter of about 5.56 millimeters (about 0.22 inches). The 5.56 mm ammunition is one of the popular calibers because it has a good combination of range, speed, and stable recoil, which makes it effective in various situations, both close and medium range combat (Jedlicka et al., 2012). Small-caliber 7.62 mm ammunition is a type of ammunition often used in firearms such as the AK-47 assault rifle, submachine guns such as the PKM, and sniper rifles such as the Dragunov. It is also commonly used in automatic machine guns and sniper rifles. With a projectile diameter of about 0.30 inches, this ammunition is known for its strong recoil and ability to effectively penetrate targets at both close and medium distances. The 7.62 mm ammunition also has a reputation for being reliable in various terrain and weather conditions (Abo El Amaim et al., 2017; Ritter et al., 2021).

Figure 2. Size comparison of small caliber ammunition, 5.56 x 45 mm NATO (left) and 7.62 x 51 mm NATO (right)

Small-caliber ammunition is usually designed to penetrate human or animal targets, not hard materials such as steel or concrete. However, the penetration capability of small caliber ammunition can vary depending on several factors, including (Abo El Amaim et al., 2017):

a. Projectile Type: Some types of projectiles, such as sharp or hard-pointed projectiles, may have better penetration capabilities than regular projectiles.
b. Trajectory Speed: The higher the trajectory speed of a projectile, the more likely it is to penetrate the target better.
c. Firing Range: Firing distance can also affect penetration capability. At closer distances, projectiles have higher kinetic energy and tend to have better penetration capability.

However, for harder target-materials such as concrete or steel, small caliber ammunition is usually ineffective in penetrating them. For such purposes, large-caliber ammunition or anti-material weapons specifically designed to penetrate hard materials are usually used (Davis et al., 2021; Dyckmans et al., 2003; Stewart & Netherton, 2020).

Table 2. Comparison of material penetration in 7.62mm and 5.56mm small caliber ammunition

Materials	**Thickness (mm)**	**5.56 mm ammunition**	**7.62 mm ammunition**
Steel	10	Good penetration	Excellent penetration
Reinforced Concrete	300	No penetration	Medium penetration
Stone Wall	500	Medium penetration	Good penetration
Ceramics	20	Good penetration	Excellent penetration
Glass	15	Good penetration	Excellent penetration

Notes:

- Excellent penetration: The ammunition is able to penetrate the material very easily and produce very significant damage that includes additional effects such as fragmentation.
- Good penetration: The ammunition can penetrate the material well and produce significant damage opposite.
- Medium penetration: The ammunition can partially penetrate the material, but not effectively and without causing significant damage opposite.
- No penetration: The ammunition is unable to penetrate the material at all.

The literature results show that 5.56 mm ammunition tends to be more effective in penetrating materials with thinner thicknesses, such as mild steel and kevlar fiber, but has limitations in penetrating thicker materials such as concrete walls and ceramics. Meanwhile, 7.62 mm ammunition shows more consistent performance in penetrating various types of materials, including materials with greater thickness such as concrete walls and aluminum (Abo El Amaim et al., 2017; Davis et al., 2021). This suggests that ammunition selection should be tailored to the conditions and characteristics of the target, where 5.56 mm caliber ammunition is more suitable for operations in urban environments or in situations where penetration of thinner materials is a priority, while 7.62 mm caliber ammunition is more suitable for operations on the battlefield or in situations where penetration of thicker materials is required (Stewart & Netherton, 2020).

Table 3. Comparison of penetration capability and factors affecting penetration in 7.62 mm and 5.56 mm small caliber ammunition

Materials	**Caliber**	**Penetration Ability**	**Influence Factor**
Lightweight Body Armor	5.56 mm	It tends to penetrate light body armor such as level IIIA bulletproof vests well.	Launch velocity, projectile design, and firing range.
	7.62 mm	Generally, has better penetration capabilities, able to penetrate light body armor more effectively.	Projectile power and material penetration capability.
Brick Wall	5.56 mm	Able to penetrate ordinary brick walls well, especially when using penetrating special ammunition.	Glide velocity, kinetic energy, and wall structure.
	7.62 mm	Usually has a good penetration ability, able to penetrate brick walls well without the need for special ammunition.	Projectile power and material penetration capability.
Light Combat Vehicle	5.56 mm	It may have difficulty in penetrating the outer layer of light combat vehicles, but it can penetrate glass well.	Glide speed, angle of attack, and structural strength of the vehicle.
	7.62 mm	It is generally capable of penetrating light combat vehicles and can cause significant damage to vehicle components.	Kinetic energy, projectile force, and material penetration capability.
Reinforced Bunkers	5.56 mm	May have difficulty in penetrating reinforced bunker walls, especially with strong concrete structures.	Projectile force, kinetic energy, and wall thickness.
	7.62 mm	It is generally more effective in penetrating reinforced bunker walls, especially if specialized penetrating ammunition is used.	Kinetic energy, projectile design, and wall thickness.
Thick Metal	5.56 mm	It may have difficulty penetrating thick metals such as ballistic steel, especially at long firing ranges.	Glide speed, angle of attack, and metal thickness.
	7.62 mm	It is better able to penetrate thick metals better, making it more suitable for fighting targets reinforced with metal.	Kinetic energy, projectile force, and metal thickness.

IV. Conclusion

Based on a comparative study of the ballistic performance of small-caliber ammunition in the penetration of different materials, a review of 5.56 mm and 7.62 mm caliber individual weapons revealed significant differences in their penetration capabilities. The results showed that 5.56 mm caliber ammunition tends to have higher velocity, but lower penetration power compared to 7.62 mm caliber ammunition. While 5.56 mm ammunition can penetrate materials such as mild steel or lightweight concrete well at close to medium range shooting distances, its ability to penetrate thicker or denser materials, such as thick steel or reinforced concrete walls, is limited. Meanwhile, 7.62 mm caliber ammunition exhibits greater penetration capabilities, being able to penetrate denser materials at longer firing ranges, making it more suitable for tasks where deep penetration is required, such as medium to long-range combat. As such, the choice between a weapon with 5.56 mm or 7.62 mm caliber ammunition should be based on the mission context and specific needs, including the type of material that may be targeted.

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