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P3_2 Thick Skin

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Abstract

We determine the thickness of human skin that would be required to be bulletproof. The kinetic energy of bullets with various calibres are determined and the tensile strength of skin used to find the stopping distance of a bullet inside skin. We find that skin with a thickness of 5-40 cm is required to be bulletproof, dependent on the calibre of the bullet. The limitations of possessing such skin are considered to determine the feasibility of a bulletproof human.

Introduction

Throughout history, humans in combat have worn armour to protect themselves from harm at the hands of weapons. Humans naturally possess protection in the form of their skin, but this is typically not thick enough to prevent harm from anything but the most trivial of weapons.

Human skin is only 2 mm thick on average [1], but if it was significantly thicker then it could, in theory, be strong enough to stop a bullet. In this paper we determine the thickness of skin required in order to stop bullets of varying calibres, and consider the challenges that possessing such thick skin might present.

Theory

Due to the vast array of bullet sizes and shapes, we are focusing on a group of 9 common handgun calibres, as shown in figure 1, to determine the relative thickness of skin required to stop each one. Each of these has a typical bullet mass m and muzzle velocity u [2] which can be used to calculate their respective kinetic energies. The kinetic energy, T, is found using the standard equation

$$T = \frac{1}{2}mu^2 \tag{1}$$

To determine the thickness of skin required to stop a bullet, we not only look at the kinetic energy, but also the maximum force the skin exerts on the bullet. This is provided by the following equation

$$F = SA \tag{2}$$

where S is the ultimate tensile strength (UTS) of skin, and A is the area of impact. We take the UTS of skin as 27.2 MPa [3] and the area of impact as 10^{-4} m^2 based on the size of the bullets. This gives a force of roughly 2700 N acting on the bullet.

The bullet will travel through the skin until it's velocity, v, reaches zero due to the deceleration, a, provided by this force. The deceleration can be found from Newton's second law. We are ignoring the effects of air resistance, as the area of the bullet is small. If this deceleration is assumed to be constant, then it can be used to find the distance a bullet will travel before stopping,

x, as a function of a and u. Substituting Newton's second law for a, the distance a bullet will travel through the skin before coming to a stop is given by

$$x = \frac{mu^2}{2F} = \frac{T}{F} \tag{3}$$

So for a given calibre of bullet, we can estimate the thickness of skin required to stop it based on it's kinetic energy, as shown in figure 1.

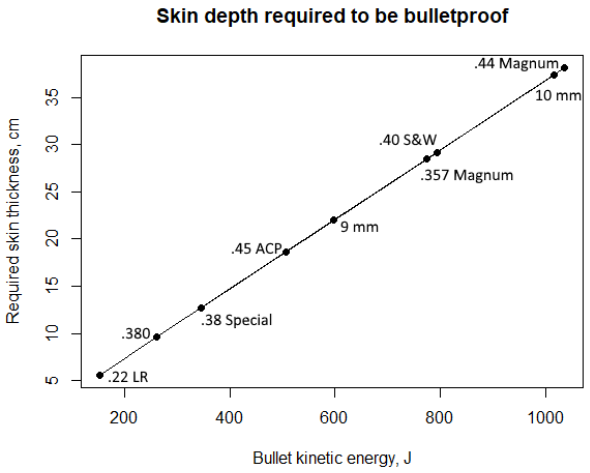

Figure 1: Estimates of the thickness of skin required to stop different calibre bullets.

Based on the figures obtained for the kinetic energy, we estimate that human skin would need to be 5-6 cm thick to stop a .22 LR bullet, and upwards of 35 cm thick to stop a .44 magnum bullet.

Discussion

Although possessing skin with a thickness of 40 cm would protect you from most bullets, it would create many other severe limitations for a person. Normal human skin is around 2 mm thick [1] on average, so to protect against even the smallest bullets considered (.22 LR) your skin would need to increase in thickness by a factor of 25. This would provide significant challenges with regards to movement of limbs and general dexterity, making everyday life rather impractical.

Carrying the extra weight due to this skin would likely also present problems. In a regular human, skin accounts for 12-15% of body weight [4]; for a person weighing 60 kg this corresponds to around 8 kg. But the weight of skin a human would require to be bulletproof would be significantly greater, many times the weight of the rest of their body. Thigh bones break under around ten times their own weight [5] so a person possessing this much skin would be unable to support themselves.

It is worth noting that we made some assumptions in these calculations that may need to be considered. We assumed the bullets all had the same impact area of 10^{-4} m^2, if this was to differ noticeably it could affect results. We also assumed the UTS of skin was constant throughout the impact. If it was found that this was not the case then the variation with impact depth and material thickness would need to be considered.

Conclusion

We conclude that it is theoretically possible for skin to be bulletproof. However the challenges presented by possessing such skin means that it would be extremely impractical to operate on a day to day basis. Traditional body armour is a much more realistic form of protection.

References

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