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P1_4 Can superhuman muscles stop bullets?

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Abstract
An attempt is made to explain the ability of Superman to jump high buildings and deflect bullets. It is hypothesised that these powers come from a superhuman density of muscle and this theory is tested and found lacking.

Introduction

In Superman's first comic book appearance it was said that he could "easily hurdle a twenty storey building...and that nothing less than a burning shell could penetrate his skin"[1]. Superman's humanoid appearance suggests a (albeit super-) humanoid physiology. This paper will investigate muscle density as the source of both his superhuman strength and his ability of bullet deflection.

Discussion

For Superman to jump a 20 storey building – approximately 100m in height – he must leave the ground at a vertical speed of $44ms^{-1}$. This assumes that acceleration remains constant, that the vertical speed at the peak of the jump is $0ms^{-1}$, that there is no effect from air resistance and that (at this point in his mythology) Superman is not immune to gravity. In order to reach this speed, from a stationary start, over the distance Superman travels between his initial crouch and take off (taken to be 0.5m), an acceleration of approximately $2000ms^{-2}$ is needed. The force required for this acceleration is,

$$F = 2000m \quad (1)$$

where m is the mass of the object being accelerated. This force is assumed to have come solely from Superman's leg muscles.

Humans muscles are composed of many microfibres, each one capable of producing approximately 0.3μN of force[2]. In practice many factors may affect the strength of a muscle including its shape and the

proportions of different fibres present, but, for the purposes of this paper, the muscle strength is proportional to the number of fibres. As, visibly, Superman's muscles are no larger than a similarly sized human's, if his physiology is similar to humans then he must have a greater muscle density.

In humans, muscle density is averaged at $1.06gcm^{-3}$[3]. In a similar way to the calculation of Superman's required force, it can be shown that human legs are capable of providing a force of approximately 800N[4]. Assuming all other things are equal, producible force will be related to muscle density, ρ_m, by,

$$F = k\rho_m, \quad (2)$$

where k is a constant of proportionality that can be calculated from the above values as approximately $750Nm^3kg^{-1}$. Again, all other things being equal, and assuming that muscle density is constant within all muscles in the body, this muscle density will relate to the total mass of the body. Using average human data; mass and the percentage volume of each type of tissue[5], mass can be found, in kg, by,

$$m = 46 + 32\rho_m. \quad (3)$$

where 46 denotes a weight term for all tissues that aren't muscles and 32 litres is the volume of muscles in the average body.

When equation (1) and (2) are set equal to one another, and equation (3) is substituted for *m,* the density of Superman's muscles can be found to be 1.48gcm^{-3}.

When investigating whether a bullet can penetrate a surface, a perforation parameter is used. This takes into account properties of both the target material and the projectile used and can be stated as,

$$P = \frac{2m_p}{\rho t A_p} \quad (4)$$

where m_p is the mass of the projectile, A_p its impacting area and ρ and t the density and thickness respectively of the target material[6]. This has been shown experimentally to relate to the speed at which 50% of bullets will penetrate the material by,

$$V_{50} = 309.13P^{-0.38708}. \quad [6](5)$$

A relatively typical handgun bullet will have a diameter of 8.585mm and a mass of 16.2g[7]. If Superman's chest muscles can be estimated as having a thickness of 5cm, a substitution of these values in to equation (4) and then (5) gives a value of V_{50} of 141ms^{-1}. Unfortunately a typical handgun will release a bullet at a speed of over 800ms^{-1}[7], indicating that Superman's chances of deflecting it based just on the density of his muscle is not high.

Conclusion

It has been shown that it is theoretically possible that Superman could power his great leaps with superdense human muscle tissue. It has also been shown that this superdense muscle alone is not enough to explain one of his other famous powers, the ability to stop bullets, so some other factor must be involved in this.

If it is assumed that, as stated specifically in the initial quote, it is Superman's skin that is able to stop bullets rather than his body as a whole, and that his skin has an average thickness similar to that of humans – 2.5mm[8] - the necessary skin density to stop 50% of typical handgun bullets is 296gcm^{-3} which is unreasonably high, even by assumed extra-terrestrial standards. This suggests that a mechanism other than simply density is behind Superman's ability to stop bullets.

References

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