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P3_8 Life with Bulletproof Skin

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Abstract

We consider some of the consequences of possessing skin thick enough to be bulletproof as determined in "P3_2 Thick Skin" [1]. We find that the extra skin would weigh 103 kg however even if this weight could be carried the temperature increase in the body would result in death in as little as 5 hours if not counteracted.

Introduction

In "P3_2 Thick Skin" it was shown that skin with a thickness of 5 cm would be sufficient to protect you from the impact of some bullets [1]. It was suggested that possessing such a skin would pose some limitations for daily life. In this paper we will consider some of the consequences of possessing bulletproof skin to determine if the scenario is feasible.

Additional Mass

Increasing the thickness of skin to 5 cm would add a substantial amount of mass to the human body. The additional mass of the skin can be estimated using the following equation

$$m_s = \rho A_s \Delta x \tag{1}$$

where ρ is the average skin density, equal to 1.090 g/cm^3 [2], A_s is the average human skin surface area, equal to 1.9 m^2 [3] and Δx is the skin depth. Using this equation with a skin depth of 5 cm we can find that the additional skin would have a mass of 103 kg. Combined with a natural bodyweight of around 60 kg this gives a total mass of 163 kg.

Heat Loss and Temperature Increase

Much of the heat generated by the body is lost through the skin by conduction. However, with significantly thicker skin the amount of heat lost would likely be much smaller. We can calculate the rate of heat loss through skin using the following equation [4]

$$\frac{dQ_{loss}}{dt} = -kA\frac{T_b - T_{room}}{\Delta x} \tag{2}$$

Where k is the thermal conductivity of skin, 0.275 W/mK [5], A is the surface area of skin on the body, T_b is body temperature, T_{room} is room temperature, taken to be 25 $°C$, and Δx is the thickness of skin. The negative sign indicates that energy is being lost from the body. Using the normal thickness of skin and body temperature, around 2 mm [6] and 37 $°C$ respectively, the typical rate of heat loss is found to be 3135 Js^{-1}.

If the thickness of skin is increased beyond the normal thickness, the rate of heat loss will decrease. This will result in the internal body temperature increasing, meaning that the rate of heat loss is a function of time. To finds this function, we use the equation below relating the

temperature increase of an object to the energy increase;

$$\Delta T = \frac{\Delta Q_{net}}{mc} \tag{3}$$

Where m is the mass of the body with the extra skin, 163 kg, and c is the specific heat capacity of the body which is 3740 $Jkg^{-1}K^{-1}$ [7]. ΔT is defined as T_b - T_0, where T_0 is the normal body temperature, and ΔQ_{net} is defined as $Q_{produced}$ - Q_{loss}. Taking the time derivative of 3 and substituting in 2 results in a first order differential equation. Solving and applying the boundary condition $\Delta T = 0\ K$ at $t = 0\ s$, we find the following expression;

$$\Delta T(t) = \Delta T_0[exp(\frac{kA}{mc\Delta x}t) - 1] \tag{4}$$

Where ΔT_0 is the normal temperature difference of 12 K. This allows us to determine the increase in body temperature at some time t, from a starting body temperature of 37 $°C$. As shown in Figure 1

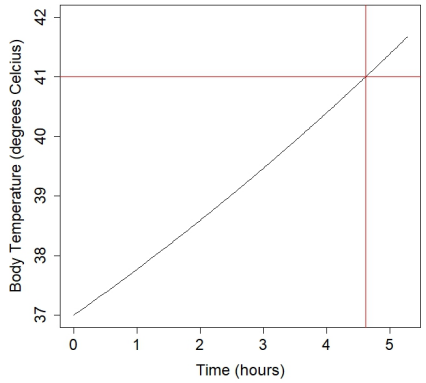

Figure 1: Graph showing body temperature as a function of time. The red line indicates the temperature at which proteins denature

Discussion

Possessing bulletproof skin would pose significant problems in everyday life. The mass of additional skin is already greater than the weight of an average human, so carrying it would require a large amount of effort. It is not a completely unreasonable weight however, and provided muscles and bones were able to support it you could survive with this skin.

The main issue comes as a result of the reduction in heat loss due to the extra skin. Proteins in the human body begin to denature at 41°C [8] which would occur at around 4.6 hours. After this point the proteins in your body would no longer function and you would likely die soon after. Therefore we conclude that possessing bulletproof skin would be fatal.

Conclusion

As had been suggested in [1] it would be impossible to survive with bulletproof skin. Whilst it may be possible to carry the additional weight, the body temperature increase would result in death in under 5 hours, rendering being bulletproof rather pointless.

References

[1] Acton et al, P3_2 Thick Skin, Journal of Special Topics 2017

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