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Do Ewoks pack a punch?

Matthew Perkins
The Centre for Interdisciplinary Science, University of Leicester
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Abstract
This paper aims to calculate the force that would be required to knock out a Stormtrooper with a rock thrown by an Ewok. In order to calculate this, the ways in which a person can get knocked out are explored, finding that the best way is to get the head to rotate in a way such that the brain hits the skull. The spin required to knock someone out was assumed, and was used to work out an angular frequency and subsequently a linear velocity. The force was then worked out, using a number of assumptions regarding the mass of a Stormtroopers head, and it was found that a force of 2797 N would be required to knock the Stormtrooper out. Therefore, the Ewok threw the rock with the same force which was 1.4 times stronger than professional featherweight boxers.

Introduction
The Ewoks are creatures native to the moon of Endor whose appearance resembles a teddy bear (figure 1; left). They were introduced in the *Star Wars* Movie, *Return of the Jedi* [1]. In this movie, the Ewoks fight the heavily armoured Stormtroopers, "birth-born human recruits" that fight for the Galactic Empire [2] (figure 1; right). Despite not being renowned for their immense strength, in one scene, an Ewok can be seen to knock out a Stormtrooper by throwing a rock, aimed at their head.

Figure 1 – (Left) Shows an Ewok, highlighting the teddy bear-like appearance [3]; (right) Shows an Imperial Stormtrooper, emphasising the heavy armour and similarities to a human [4].

It is possible to calculate the amount of force that the Ewok exerted on the rock, by looking at the science behind knocking the person out, assuming that the Stormtroopers are similar to humans. By extension, working out the force applied to the rock that was thrown, can give an indication of the strength of the Ewoks.

Theory and application
The brain is a vastly complex and important organ in the body located in the skull, made of nerves and blood vessels. The brain is suspended in a liquid called the cerebrospinal fluid, which normally helps prevent the brain from making contact with the skull [5]. However, if a large enough force is applied to the head, the brain can make contact with the skull. Since the brain is so fragile, the physical impact causes the brain to fire many neurotransmitters simultaneously causing the nervous system to shut down, and effectively knocking out the person [5].

The most effective way for the brain to hit the skull in such a manner is for the jaw or chin of a person to be hit with the right angle and force. The reason for this is that hitting a person in this location causes the head to rotate, and thus causes the most movement of the brain in the skull [6]. Therefore, when calculating how hard the rock was thrown at the Stormtrooper, it will be assumed that the rock hit them in this rotational manner.

It has been found that a blow that can cause the head to accelerate from 0 to 43,000 rpm in 1 second, has a 25 % chance to knock a person unconscious [7].

If it is assumed that this is the amount of spin that was required to knock out the Stormtrooper, the angular frequency, ω, of this movement can be worked out using equation 1 [8] to be 4503.0 rads^{-1}.

$$\omega = \frac{2\pi(RPM)}{60}. \quad (1)$$

In order to turn this angular frequency into a linear velocity, v, equation 2 can be used:

$$v = \omega r. \quad (2)$$

In this equation r is the radius of the circle that the Stormtrooper's head undergoes in the impact. Figure 2 shows the movement of the head, and shows how the radius will be modelled:

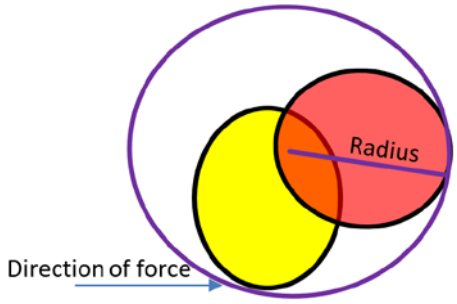

Figure 2 – The movement of the Stormtroopers head from a top down view, the yellow circle is the original position, the red circle is the final position. The purple circle represents the path the head takes, with the neck at the centre, representing the pivot. The radius is measured from where the neck is located to the new position of the front of the head.

The head will be modelled to rotate around the neck, so will be seen to be acting as a pivot. If the neck is assumed to be directly at the centre of the head the radius of the head will be used as the radius of the circle of rotation. The average diameter of a male's head is approximately 18 cm [9], and so the radius that will be used will be 9 cm. Therefore, if this number is substituted into equation 2, along with the angular frequency, a value of 405.3 ms^{-1} is generated.

The rock hitting the Stormtrooper must cause their head to move with a linear velocity of 405.3 ms^{-1}. Using Newton's second law of motion (equation 3), it can be seen that in order to work out the force required to knock out the Stormtrooper, the mass of the head has to be assumed.

$$F = ma. \quad (3)$$

The mass of the Stormtroopers head will be assumed to be 5 kg, which is approximately the same as a human head [10]. However, since the Stormtroopers are wearing helmets, an extra 1.9 kg will be added to the weight, which is equal to a Kevlar helmet used in the military [11].

The acceleration, a, of the head is equal to equation 4, and since the motion must be completed in a second, time, t, will be equal to 1. Therefore, the acceleration in this case will be equal to the velocity.

$$a = \frac{v}{t} \quad (4)$$

Substituting these numbers into equation 3 generates a value of 2797 N of force transmitted from the rock to the Stormtroopers head. If it is assumed that there is no energy loss in the entire process, the Ewok threw the stone with this same force.

To put this into context a study of Olympic boxers found that the strongest punches ranged from 4742 N for heavy weight, and 1988 N for feather weights. This means that the Ewok could throw the rock with 1.4 times the force of professional feather weight boxers, and over half the force of a heavy weight boxer [12].

Considering these creatures are supposedly only a metre tall, and weigh in at approximately 50 kg [13], it seems unlikely that their force output exceeds that of a featherweight boxer. An explanation for this could be because the Ewok threw the rock using a sling as oppose to throwing the rock directly at the Stormtrooper. The sling could have generated more force, and so may not be a perfect reflection of the Ewoks strength.

Conclusion

The Ewok was found to throw the rock with force of 2797 N, by using a rotational model to knock out a person. The assumptions used were that the Stormtrooper was similar to a human and thus required the same amount of spin to knock them out. Then equations for angular frequency, linear velocity, Newton's second law and acceleration were used. The force that the Ewok was calculated to be able to exert was found to be 1.4 times that of a professional boxer.

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