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Abstract

The farthest archery target hit ever was achieved from a distance of 330 m. In this paper we estimated that a shot of this distance would require a force of 100 N (2 s.f) to be achieved. We conclude it is within human capabilities to improve on this record but ensuring the accuracy of the shot so the target is actually hit poses a challenge to any who try to break the record.

Introduction

According to the Guiness Book of World Records, the farthest archery target hit was achieved by american Tyler Toney from a distance of 330 m in September 2022 [1]. In this paper we investigate the force required to make the shot by modelling the arrow as a projectile. We will then discuss whether or not it is reasonable that this record could be broken in the future.

Theory

Projectile motion describes the curved path of an object when it is launched and subsequently allowed to move freely [2]. The velocity horizontally is always uniform but vertically the acceleration is uniform as the acceleration due to gravity is constant. Projectile motion assumes external factors such as air resistance are negligible. This yields a number of useful equations to describe the motion and path of any projectile. Applying these to an archery shot will then let us estimate the force required to hit the target. Finding the initial speed of the arrow will allow us to calculate it's acceleration from rest over the bow's draw distance. Newton's Second Law tells us the acceleration of an object is proportional to the net force acting on it [2] so we can then substitute this acceleration in to estimate the force required to launch the arrow so it hits the target 330 m away.

Results

The equation for horizontal range for a projectile is:

$$R = \frac{u^2 sin(2\theta)}{g}, \tag{1}$$

Where R is the horizontal range (330 m in this case), u is the initial velocity of the arrow, g is the acceleration due to gravity (9.81 ms^{-2} on Earth) and θ is the angle of projection. We can rearrange this in order to calculate the initial velocity of the arrow,

$$u = \sqrt{\frac{Rg}{sin(2\theta)}}, \tag{2}$$

The smallest u (and thus the least force required to make the shot) would be achieved where the $sin(2\theta)$ term is largest so we have selected an angle of projection of 45° to maximise this term. This yields an initial velocity for the arrow of 57

ms^{-1} (2 s.f). In order to find the force it would take to accelerate an arrow from rest to this velocity we need to find the time it took for this acceleration to take place. The draw length of a bow ranges from about 23 inches to 30 inches [3] for our estimate we will assume a draw of approximately 30 inches as it is a professional taking the shot. The time is then simply calculated by dividing the draw distance by the velocity of the arrow. Acceleration can then be found using,

$$a = \frac{(u - v_0)}{t}, \tag{3}$$

where u is the velocity of the arrow at launch, v_0 is the the arrow's starting velocity,in this case it is at rest, and t is the time it is accelerated for. This gives an acceleration of 4200 ms^{-2} (2 s.f). Finally, we can use Newton's Second Law of Motion,

$$F = ma, \tag{4}$$

where F is the force required to launch the arrow, a is the acceleration and m is the mass of the arrow taken to be 24 g (2 s.f) [4] to estimate the force. This yields a force of 100 N (2 s.f).

Discussion

100 N is a reasonable result as it is lower than the greatest pull strength recorded for a human male of 400 N [5]. This implies it is theoretically possible for the farthest target hit to be improved upon but it would have to be a particularly strong archer. Furthermore, it is not just about increasing the distance but ensuring the flight of the arrow is accurate enough to hit the target. Tyler Toney's record breaking shot was undertaken with a team of people placed near the target in order to advise him on how to adjust his shot so he would strike the target. If this method was repeated it is possible to break his record but would likely take several attempts and a bit of luck.

Above we have discussed if the shot could be improved upon if it was taken by pulling the bow with one's arm however Tyler Toney's record breaking shot was actually performed with his leg as he is an amputee. A human leg can exert a force of about 800 N [6] thus should be able to launch an arrow to greater distances than a shot taken with one's arm. This makes the breaking of the farthest target hit much more likely. Overall, we feel the force humans are capable of exerting means this record could theoretically be broken but any attempt would be hindered by the accuracy required to actually hit the target.

Conclusion

In conclusion, we estimated a force of 100 N (2 s.f) to make Tyler Toney's world record target hit of 330 m. By considering the capabilities of human beings we believe it is technically possible for this world record to be improved upon. However, ensuring the shot is accurate enough to hit the target is a challenge and something that requires further consideration.

References

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