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S3_1 Setting the Record Straight

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Abstract

We investigate the outcome of performing world record sports events on the Moon with reduced gravity. We studied men's shotput and $100m$ sprint; held by Randy Barnes ($23.12m$) and Usain Bolt ($9.58s$) respectively. After calculating the world records attempts on the moon, we found that the shotput record would increase to $168m$ and the $100m$ sprint record would slow to $10.0s$.

Introduction

In this paper, we investigate how world record attempts for shotput and sprinting would differ if attempted on the Moon. We expect that the shotput record will improve and the sprint will worsen. We have analysed the dynamics of the sports to test the outcome of reduced gravity. We assume that the athletes engage in their respective sports immediately after landing on the Moon to prevent any muscle mass loss and that the athletes have the same oxygen capacity as on Earth, wearing protective suits of negligible mass.

Theory

In shotput, Randy Barnes holds the current world record with a distance of $23.12m$ [1]. To calculate the theoretical Moon record attempt, we assume the shot is thrown from the height of Randy Barnes $1.95m$ at an angle of 40 degrees, the optimum angle when throwing a shot [2], which has been assumed to be independent of gravity.

We combine equations 1 and 2, and rearrange to find the initial velocity of the shot during the world record attempt, as shown in equation 3. The drag on the shot is neglected on both the Earth and Moon.

$$x = ut\cos(\theta) \tag{1}$$

where x is final horizontal position, u is initial velocity of the shot, t is time of flight and θ is the angle the shot is thrown at.

$$y = y_0 + ut\sin(\theta) + \frac{1}{2}at^2 \tag{2}$$

where y is final vertical position, y_0 is the initial vertical position, and a is acceleration.

$$u = \sqrt{\frac{-\frac{1}{2}ax^2}{y_0 + x\tan(\theta)}}\frac{1}{\cos(\theta)} \tag{3}$$

On the Moon, assuming the same initial velocity of the shot, we use equation 4 to calculate the height that the shot would reach.

$$y_{max} = \frac{v^2 - (u\sin(\theta))^2}{2a} \tag{4}$$

where y_{max} is the height the shot will reach and v is the final velocity of the shot.

We calculate the total time of flight of the shot using equations 5 and 6 for the shot travelling up then down respectively.

$$t = \frac{v - u}{a} \quad (5)$$

$$t = \frac{-u \pm \sqrt{u^2 - 4(\frac{1}{2}a)(s)}}{2(\frac{1}{2}a)} \quad (6)$$

This time of flight and the horizontal component of the initial speed of the shot in equation 7 are used to calculate the horizontal distance the shot would travel.

$$x = uT \quad (7)$$

where T is the total time of flight calculated by taking the sum of equations 5 & 6.

Usain Bolt is the current world record holder for the $100m$ sprint with a time of $9.58s$ [3]. When Usain Bolt runs, he takes, on average, 41 strides over $100m$ [3]. We assume Usain's leg is lifted $0.7m$ with each stride.

We start by calculating the deceleration of half a stride, that is, Usain's leg from the top of his stride to the floor. We split the acceleration into two components coming from the force due to gravity and the force provided by his leg muscles.

Using equation 8 we found the acceleration due to Usain's leg muscles.

$$x = vt - \frac{1}{2}at^2 \quad (8)$$

We use equation 8 again, this time rearranging for time. This is multiplied by 82 to obtain the time taken for the $100m$ sprint.

Discussion

We find the initial velocity of the shot to be $14.6ms^{-1}$ on the Earth. On the Moon, we find the maximum height of the projectile is $27.1m$. We find the time of flight for the shot to be $15.0s$. From this, the shotput Moon record would be $168m$. The range calculated for the shot is larger than expected but when considering the difference in gravity, does seem reasonable. The record for shotput would be much improved on the Moon according to our calculations but in reality Barnes' technique could be affected in an unfamiliar environment if the world record was attempted.

For the $100m$ sprint, we find the time per half a stride on the moon to be $0.122s$ which gives a total time of $10.00s$. This is only slightly slower than on Earth. This is justified since in sprinting the main power comes from Bolt driving his feet into the ground and he would not be vastly affected by the decreased gravity. Sprinting is more difficult to model simply than shotput so aspects of friction and drag have been neglected in this paper and should be analysed to improve this result.

Conclusion

We have looked at the difference in sports on the Earth and Moon by comparing shotput and $100m$ on both planets. Our projectile calculations find that the world record for shotput would improve from $23.12m$ on Earth to $168m$ on the Moon. The acceleration due to gravity influences the height and range of a shotput ball massively for this result. The world record for $100m$ sprint would slow down from $9.58s$ to $10.0s$. It is worth noting that this result may differ if friction were taken into account, so this is suggested as future work in this area, however is beyond the scope of this paper.

References

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