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A4_5 Eternal Punishment?

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Abstract

This paper considers the Greek character Sisyphus, and finds the energy expended as he undertakes his punishment in Tartarus. We find the energy expended the first time he rolls the boulder up to be ≈ 57.4 kcal, and this decreases exponentially with each roll as he loses mass. Finding the mass of fat he would lose each time, we determine that the maximum number of times Sisyphus would be able to roll his boulder to the top of a hill to be 2579.

Introduction

Sisyphus was a character in Greek mythology, who tricked Thanatos, the god of death, and was sent to Tartarus, the deepest part of hell. He was condemned to roll a boulder to the top of a hill, and upon reaching the summit, the boulder would roll back down again. Sisyphus was made to carry out his futile labour for all eternity [1]. This paper looks at the energy required for Sisyphus' labours, and by assuming this energy comes from fat reserves, calculates the mass Sisyphus would lose with each attempt.

Method

To determine the energy expended by Sisyphus, we consider he must roll a boulder uphill over a distance of 100m, to an peak altitude of 10m, representing a typical steep hill. The angle of incline can be calculated using trigonometry to be $\theta = 5.7°$. The boulder in question is modelled as a sphere with a radius of 0.4m. The volume of a boulder with 80cm diameter is 0.27m^3 and the density of stone is 2500kgm^{-3} [2], therefore the mass of the boulder is 675kg.

Work done moving boulder: The work done to move the boulder up the hill can be calculated from:

$$W = -M_B g h \tag{1}$$

where h is the height of the hill, 10m, and g is gravity (9.81ms^{-2}). Therefore the work done (W) moving the boulder uphill is 66150J. This can be converted into kilocalories by dividing by 4184 [3], hence the energy required to push the boulder to the peak (E_B) is 16kcal.

Work done walking uphill: In addition to the work Sisyphus must do to move the boulder, work is also done as he walks uphill. The energy expended by the average human walking up a hill with a 10% gradient is:

$$E_W = 0.14m \tag{2}$$

where m is the mass of Sisyphus, and E_W is expressed in kilocalories per minute [4]. If we consider Sisyphus to be walking at an average speed of 1.5kmh^{-1}, then it takes him 4 minutes to roll the boulder up the hill. Therefore, the total energy expended as he walks up the hill is 0.52mkcals.

Metabolic Energy: In addition to the energy required for him to move the boulder, energy is also expended due to metabolic processes within the body. The equation for the energy required per day for an average man to carry out these processes is:

$$E_{BMR} = 10m + 6.25h - 5a + 5 \quad (3)$$

where m is the person's mass, h their height, and a their age [5]. Therefore, assuming Sisyphus height and age to be 170cm and 35yrs respectively, his BMR is $(10m + 892.5)$kcal. As stated previously, we assume it takes 4 minutes for Sisyphus and his boulder to reach the top. Accounting for an additional minute during which the boulder rolls back down to the bottom, Sisyphus can complete the act 288 times per day, meaning the metabolic energy expended over the course of each attempt is (0.035m+3)kcal.

Total Energy: From the above, we find that the total energy required each time Sisyphus rolls the boulder up the hill to be expressed as:

$$E_T = E_B + E_W + E_{BMR} = Am + B \quad (4)$$

where A & B are constants (equal to 0.555 and 19) respectively.

Mass Loss

The energy required comes from the fat reserves in Sisyphus' body. Body fat contains 7770kcal kg^{-1} [6], therefore the mass lost with each attempt to get the boulder to stay at the summit is:

$$\frac{dM}{dn} = \frac{E_T}{7770} = Cm + D \quad (5)$$

where n is the number of attempts, and C & D are constants (7.14×10^{-5} and 0.0024 respectively). We can solve the above equation to find the mass of Sisyphus as a function of the number of times he pushes the boulder to the top. This allows us to determine the maximum number of times a living Sisyphus would be able to complete such a task, as the mass loss cannot exceed his total fat reserves. The mass of Sisyphus can be expressed as:

$$M(n) = M_0 - \frac{C}{D}(e^{Dn} - 1) \quad (6)$$

as shown in Figure 1.

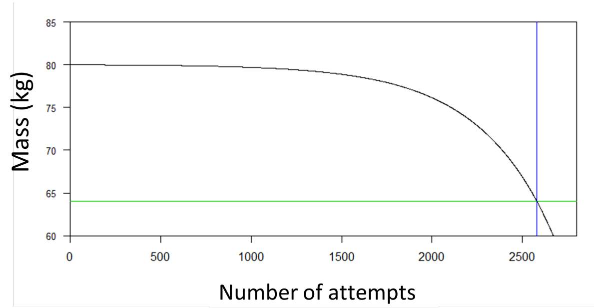

Figure 1: Graph showing body mass as a function of number of attempts to push boulder uphill, green line indicates mass where fat reserves are exhausted, blue line indicates the corresponding number of rolls.

Conclusion

Assuming a starting mass of 80kg, and a starting body fat percentage of 20%, Sisyphus' fat reserves would be emptied after 2579 attempts at pushing the boulder to the top, (or 8.95 days). His eternal punishment, therefore, would not be eternal if he were living, rather his suffering would be complete in just over a week. A number of assumptions have been made to simplify the problem, including the neglect of the rolling properties of the boulder when moving it uphill, and that Sisyphus carries out his labours without stopping for water or sleep, at a consistent effort.

References

[1] https://www.britannica.com/topic/Sisyphus [Accessed 6/12/2020]

[2] https://tinyurl.com/y82yeytw [Accessed 6/12/2020]

[3] https://tinyurl.com/y32d2dsr [Accessed 6/12/2020]

[4] https://tinyurl.com/y6y9tfaz [Accessed 6/12/2020]

[5] https://www.calculator.net/bmr-calculator.html [Accessed 6/12/2020]

[6] https://tinyurl.com/yy3gzt7e [Accessed 6/12/2020]