Journal of Interdisciplinary Science Topics

# How high does Paper Mario have to jump to match the strength of his regular counterpart?

Nadia Al Hashemi
*Honours Integrated Science, McMaster University*
28/03/2018

**Abstract**
The video game superstar Mario is well known for his jumping ability. In the spin-off game, Paper Mario is similarly well-known but is physically made of paper. This paper explores the differences in the impact force between regular and Paper Mario and calculates the jump height Paper Mario would need to attain in order for him to carry the same impact force as regular Mario. To do this, Paper Mario is assumed to be a rectangular sheet of paper, and the same height as regular Mario, but much less dense. From calculating the impact force from regular Mario to be 17.3 kN, it was found that in order to match this force, Paper Mario would need to attain a height of 47.6 m. As a result, while it is possible for Paper Mario to match Mario in damage, it is unrealistic that he would be able to do so. He can however, jump multiple times on enemies which would increase his damage output.

**Introduction**
Nintendo's Mario is a well-known cultural icon who has appeared in nearly all types of media. From live action television to movies to video games, Mario is best known for stomping on enemies. However, something that may not be as well known about Mario is that he has also been represented as a simple slip of paper. *Paper Mario* was first released in Japan on August 11, 2000 [1]. In this game, Mario, his companions, and the world he inhabits are all made completely out of paper.

This raises an interesting question; how does the strength of Paper Mario compare to his regular flesh and body counterpart? The most obvious comparison to make would be Mario's ability to jump and crush his enemies. By looking at the force Mario exerts when landing on a Goomba, his impact force can be calculated and compared to Paper Mario's, as well as how high the paper plumber would need to jump to deal the same amount of damage.

**Measurements for Mario and Paper Mario**
No official height is given for Paper Mario, so regular Mario's measurements will be used instead. Mario's height has been changed over the years, but in general has landed at around 156 cm, with a mass of 50 kg [2]. In this paper, Paper Mario will be modelled as a rectangular sheet of paper with the same height as regular Mario for simplicity. This is a justified assumption, as in the sequel game *Paper Mario: The Thousand Year Door*, Paper Mario when folded is clearly shown to be modelled on a rectangular sheet of paper [3]. He will be assumed to be made out of bond paper, which is typically 90 μm thick and have a grammage, or $gm^{-2}$, relationship of 60 $gm^{-2}$ [4]. These papers are normally 21.5 × 35.5 cm. By keeping this ratio and substituting in Paper Mario's height as the length, Paper Mario would have an area of 94.5 × 156 cm, or 147.4 $m^2$, and mass of 8.84 kg [4]. It will be assumed that Paper Mario is not subjected to crumpling, as he does not do so in his own game [1].

**Calculating Mario's jump height**
To find the force needed for Paper Mario to crush a Goomba, it can be assumed that Mario, in the act of crushing the Goomba, will leap to his full height and fall directly on top of the Goomba, the downwards force exerted by landing being enough to crush the Goomba. The Goomba does not have an official listed height. However, when looking at the official height comparison chart, Goombas are shown to be around half of Mario's height, and their height can therefore be estimated to be around 78 cm tall [5].

With this information, the regular and Paper Mario's maximum jump heights need to be calculated. PBS Digital Studios used Mario's jump time in their Super Mario World video, and had calculated that from start to finish, Mario spends 0.6 s in the air when jumping from the ground until landing on a point of equal elevation [6]. His jump height was also separately observed to be approximately around 2.25 times his own height in game – knowing this, Mario's maximum jump height is shown to be around 348.75 cm, or 3.5 m. However, by looking at equation 1, we can see that these numbers would not make sense if we use the constant $g$, which is typically 9.81 ms$^{-2}$;

$$h = \frac{g\left(\frac{t}{2}\right)^2}{2}, \tag{1}$$

where $h$ is the maximum height of Mario, and $t$ is the total time spent in the air, from start to finish [7]. Plugging in the regular Mario's jump time of 0.6 s spent in the air to equation 1, regular Mario's maximum jump height is found to be instead 0.44 m. This inconsistency shows that the Super Mario world has a different $g$ constant than on Earth. By plugging in the measured $t$ and $h$, the $g$ in this scenario is found to be around 77.5 ms$^{-2}$. By instead using this new $g$ value and the maximum height, the force of impact can now be calculated.

$$U = mgh, \tag{2}$$

$$W = Fd, \tag{3}$$

By taking into account that this is a vertical jump starting at $v = 0$ at the apex of the jump, all the work ($W$) will have come from the potential energy ($U$). Equations 2 and 3 can be rearranged to form equation 4;

$$F = \frac{mgh}{d}, \tag{4}$$

where $m$ is Mario's mass, $h$ is the maximum jump height, and $d$ is the stopping distance. As Mario typically completely compresses the Goomba in game, the stopping distance will be treated as the height of the Goomba, or 78 cm off of the ground. By substituting in regular Mario's mass, maximum jump height, new $g$ constant and stop height in this scenario, regular Mario deals an impact force of 17.3 kN. Comparatively speaking this value is nearly eight times the force required to crush a human skull [8]. The extreme impact force exerted from Mario is likely due to the differing conditions of his world, as well as his renowned jumping prowess. This extreme leg strength has been pointed out before as an explanation as to his jump height and crushing ability [6].

**How does Paper Mario compare?**

Paper Mario's jumps have never actually been properly timed but can also be estimated through gameplay footage. By looking at this footage Paper Mario has an estimated jump time of 1.08 s and a maximum jump height of three times his own height, or 468 cm [9]. From here, the $g$ constant on Paper Mario's world can be calculated through equation 1 to be 32.1 ms$^{-2}$. Finally, the impact force for Paper Mario can be calculated using equation 4 once again, which is found to be a surprising 1.70 kN. Predictably, this value is much smaller than the denser regular Mario's. In fact, to match the impact force of regular Mario, Paper Mario would have to jump 47.6 m, or approximately 30.5 times his own height, and around 13.6 times the regular Mario's jumping height.

While Paper Mario is unable to match the damage done by regular Mario with one jump, Paper Mario has access to another skill: multi jumping. By jumping on an enemy, Paper Mario can bounce off them back up to maximum height and is able to jump on enemies a second time, up to two times in succession [1]. If Paper Mario were to jump repeatedly in the same spot, the apparently weak in comparison damage could build up, leading to the potential of dealing enough damage to cause some bone fracture in smaller bones. However, this is still nowhere near the damage inflicted by regular Mario.

**Conclusion**

Assuming that 156 cm tall Paper Mario uses his multi-jump technique, it is possible for him to do some damage to a person, though evidently nowhere near that of the regular Mario. While regular Mario had an impact force of 17.3 kN, Paper Mario only had a comparatively smaller impact force of 1.70 kN, and to match regular Mario's force of impact, would have to jump over 13 times the jump height of regular Mario. In the future, it may be beneficial to look into how Paper Mario or his enemies may crumple on impact, as they are both made out of paper.

**References**

[1] Nintendo (2000) *Paper Mario*, [Computer game] Nintendo 64, Nintendo, Japan.

[2] Anon (2019). *Height and Weight Guide*. [online] Super Mario Luigi Bros. Wiki. Available at: https://super-mario-luigi-bros.fandom.com/wiki/Height_and_Weight_Guide [Accessed 16th February 2019].

[3] Nintendo (2004) *Paper Mario: The Thousand Year Door*, [Computer game] GameCube, Nintendo, Japan.

[4] Canadian General Standards Board, (2014). *Bond Paper*. [Online] Government of Canada Publications. Available at: http://publications.gc.ca/collections/collection_2017/ongc-cgsb/P29-5-009-001-1993-eng.pdf [Accessed 22th February 2019].

[5] Nintendo (2008). *Universal Size Chart*. Super Mario Bros. Wiki. Image uploaded by Bloc Partier. Available at: https://www.mariowiki.com/File:Size_chart.jpg [Accessed 25th February 2019].

[6] Perez-Giz, G. (2015) *What Planet Is Super Mario World?* PBS Space Time, Season 1. [TV episode]. PBS Digital Studios. First Broadcast 11th February 2015.

[7] Moir, G.L. (2008) *Three Different Methods of Calculating Vertical Jump Height from Force Platform Data in Men and Women*. Measurement in Physical Education and Exercise Science, 12(4), pp.207–218.

[8] Mattei, T.A., Bond, B.J., Goulart, C.R., Sloffer, C.A., Morris, M.J. & Lin, J.J. (2012) *Performance analysis of the protective effects of bicycle helmets during impact and crush tests in pediatric skull models: Laboratory investigation,* Journal of Neurosurgery: Pediatrics, 10(6), pp.490–497.

[9] NintendoMovies (2019) *Paper Mario 64 - Full Game (Walkthrough, Everything)*, YouTube. Available at: https://www.youtube.com/watch?v=6wQzSVIwYZI [Accessed 16th February 2019].