Journal of Interdisciplinary Science Topics

"The Fastest Man Alive" – but how?

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17/04/2018

Abstract

Although the Flash is considered the fastest man alive, the nature of his speed is poorly understood. This paper explores the biomechanics and neurophysiology of the Flash's speed during a 100 m sprint. The results show that the Flash must apply 13.9 MN of force in a single step from his starting position in order to accelerate to his maximum velocity of 4472.44 ms^{-1} in a 100 m dash. Moreover, exerting such forces requires a substantially high nerve conduction velocity, which can be achieved by increasing myelin thickness and axon diameter. Future studies should quantify this conduction velocity, as well as its accompanying myelin thickness and axon diameter.

Introduction

Publications in this journal consistently state that the Flash – a fictional character – is the fastest man alive [1-5]. However, the necessary conditions for his speed have not been studied. Thus, this paper examines biomechanical and neurophysiological properties that allow him to achieve his maximum velocity (4472.44 ms^{-1}) over 100 m; this velocity was previously calculated [1].

Biomechanics of Sprinting

Like all sprinters, the Flash accelerates to maximum velocity from his starting position [6]. This involves crouching down and leaning forward so that his body is as horizontal as possible relative to the ground. Through this position, the Flash exploits Newton's Third Law of Motion: the force exerted by object A on B ("action") is equal in magnitude and opposite in direction to the force exerted by object B on A ("reaction") [7]. For the Flash, "action" is the force he applies on the track ($F_{applied}$) and "reaction" is the force the track applies on him ($F_{propelled}$); the latter propels him forward. Equation 1 shows this:

$$F_{applied} = -F_{propelled} \tag{1}$$

Based on equation 1, the Flash's $F_{applied}$ must be incredibly strong to ensure a sufficient $F_{propelled}$ to drive his acceleration to maximum velocity. However, if his starting position is not sufficiently horizontal, a greater portion of $F_{propelled}$ will be directed vertically, making his acceleration suboptimal (figure 1).

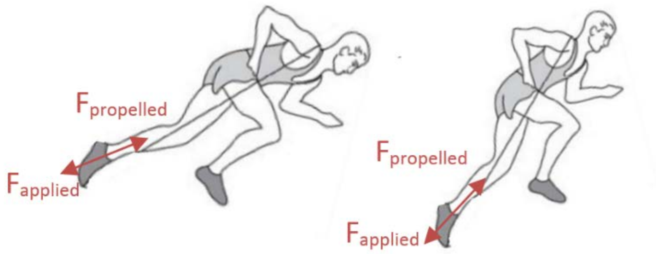

Figure 1 – $F_{applied}$ and $F_{propelled}$ are equal and opposite forces [7]. Horizontal starting positions (left) direct greater portions of $F_{propelled}$ forward than vertical starting positions (right) [6, 7].

Calculating the "Action" Force

In reality, sprinters can direct about 77-79 % of $F_{applied}$ horizontally, with the rest being directed vertically [8]. However, this paper assumes that the Flash can direct 100 % of $F_{applied}$ horizontally; as such, his net force (F_{net}) can be modelled using equation 2 [9]:

$$F_{net} = F_{propelled} - F_{drag} - F_F, \tag{2}$$

where F_{drag} is from air resistance acting against the Flash and F_F is from the friction between the track and his shoes [9]. Calculating $F_{propelled}$ using this model also provides $F_{applied}$ as both are equal in magnitude.

First, F_{net} can be found by multiplying the Flash's mass by his acceleration (a); the latter can be found using equation 3 from kinematics:

$$a = ({v_2}^2 - {v_1}^2)/2\Delta d, \quad (3)$$

where v_1 is the Flash's initial velocity (0 ms^{-1} since he begins at rest), v_2 is his final velocity (4472.44 ms^{-1}), and Δd is his displacement (100 m) [1]. Inputting these values into equation 3 gives an acceleration of 100013.60 ms^{-2}. Multiplying this by the Flash's mass (84 kg), F_{net} equals 8401142.21 N. The mass was assumed to be 84 kg since this value was previously used to find the Flash's maximum velocity [1].

To calculate F_{drag}, equation 4 can be used [9]:

$$F_{drag} = 0.45 \times \rho_{air} \times v^2 \times A, \quad (4)$$

where v is the Flash's velocity (4472.44 ms^{-1}), A is his frontal area (roughly 0.5 m^2), ρ_{air} is the density of air (1.225 kgm^{-3} assuming 15 ^oC at sea level), and 0.45 is a constant [9, 10]. Inputting these values into equation 4 gives F_{drag} as 5513249.58 N. It is important to note that this calculation is simplified by assuming the Flash's final velocity to be constant, even though in reality it is reached during his acceleration. Thus, the F_{drag} reported in this paper overestimates the impact of air resistance on the Flash's 100 m dash.

Lastly, F_F can be calculated using equation 5 [9]:

$$F_F = \mu_S \times F_N, \quad (5)$$

where μ_S is the coefficient of static friction and F_N is the normal force. Assuming the Flash wears rubber-soled shoes on a standard polyurethane track, μ_S is 0.67 [11]. The coefficient of kinetic friction is not included since he does not slide; his step is a source of static friction. Next, multiplying the Flash's mass (84 kg) by his acceleration due to gravity (9.81 ms^{-2}) results in F_N being 824.04 N. Substituting μ_S and F_N into equation 5 gives F_F as 552.11 N.

Finally, F_{net}, F_{drag}, and F_F can be substituted into equation 2 to find $F_{propelled}$ as being 13914943.90 N, or 13.9 MN. Since $F_{propelled}$ equals $F_{applied}$ are equal in magnitude, the Flash must apply 13.9 MN of force in a single step to accelerate to his maximum velocity of 4472.44 ms^{-1} in 100 m. This is significantly larger than the 1186-1224 N exerted by the average sprinter [12].

Neurophysiology of Sprinting

In order for the Flash to contract the muscles needed to exert 13.9 MN of force, his brain must signal their contraction using action potentials (APs) [13, 14]. The more AP stimulation a muscle receives, the stronger the force it can apply [13, 14]. However, APs are limited by two factors. First, they are "all-or-none" processes; no one AP is "stronger" than another [14]. Second, successive APs are separated by the neuron's refractory (rest) periods [14]. Given these limitations, the only other way to increase the Flash's muscle stimulation is by increasing the speed at which APs travel down the neuron ("conduction velocity") [15, 16]. This allows more APs to reach his muscles in a given time period, resulting in greater stimulation and thus, force of exerted. To increase conduction velocity, the Flash's neurons must have increased myelin thickness and axon diameters [15, 16].

The conduction velocities of myelinated neurons (150 ms^{-1}) are higher than those of unmyelinated neurons (10 ms^{-1}) since myelin insulates the axon [14-16]. Insulation reduces ion leakage from the axonal membrane, which maintains the voltage difference needed to fire APs ("threshold"); this allows for uninterrupted AP propagation [15, 16]. Unmyelinated neurons do not offer insulation; their significant ion leakage moves the membrane voltage away from threshold, disrupting AP propagation and thus, dramatically slowing its flow [15, 16]. With respect to the Flash, the previously calculated 13.9 MN of force is an incredible amount to exert; the necessary conduction velocities to do so cannot be achieved through standard myelination. However, increasing myelin thickness can raise conduction velocity by the same factor, as the two are linearly related [15]. Thus, the Flash's neurons can further enhance their conduction velocities if their myelin sheaths are significantly thicker than those of an average human. Furthermore, wider axon diameters can complement the effects of increased myelin thickness by reducing the internal resistance to AP flow; this is similar to water flowing more easily through a wider hose than an obstructed one [15, 16].

Conclusion

This paper concludes that the Flash must exert 13.9 MN of force in a single step in order for him to accelerate to his maximum velocity in a 100 m dash. It also explains that increasing myelin thickness and axon diameter improve conduction velocity, enabling greater stimulation of the Flash's muscles and thus, increasing the amount of force they can apply. Future publications can build on this work by calculating the conduction velocity of the Flash's neurons and its accompanying myelin thickness and axon diameter.

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