The Absorption of Water by Humans

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1 Introduction

Many people run through the rain in a hope of reducing the amount of water they absorb on there journey. We analyse here the success of this instictive approach to the problem, and propose new possibilities for reducing the amount of water absorbed.

We will model rainfall as a fluid falling vertically downwards with a constant velocity. And we shall approximate the human body by a cuboid moving through this falling fluid. We shall make no attempt to include the rate of drying into our equations, and as such will assume the human is made of a perfectly absorbant material. Presumably an imperfectly absorbing human could be accounted for in this model by a reduction in the density of the rain.

We shall also briefly discuss saturation which is expected to remove the troublesome singular behaviour which we find in our model.

2 Calculations

2.1 The Human Body

We approxiamte the human body by a cuboid of height h width a and length l (which corresponds to the distance from the back to the front of the head). This is discussed in greater detail in [1].

We suppose this human has to travel a distance d, and does so at a speed v. Hence the time taken for the journey will be

$$t = \frac{d}{v} \tag{1}$$

2.2 The Rain

We model the rain by a fluid of density ρ falling vertically downwards with velocity w. Hence, in a time t a drop of rain will move a distance wt.

If we expose an area A perpendicularly to the rain for a time t the volume of rain passing through the surface will thus be Awt, and so the mass of water absorbed by an area A in time t is given by

$$M = \rho A w t \tag{2}$$

We therefore need to calculate the area perpendicular to the rainfall which is exposed when moving through the rain.

2.3 Human Rest Frame

It is easier to calculate our result if we switch to a frame in which the human is not moving [2]. In this frame the rain can be considered as falling diagonally towards the human. The downwards component of the velocity will still be w, but now the rain has a horizontal component to its velocity given by v (pointing towards the human).

We see from Fig 1, using some simple trigonometry, that the length

$$x = l + h\frac{v}{w} \tag{3}$$

gives us the length of the perpendicular area exposed to the rain.

The width of the perpendicular area, a, is unchanged and so the perpendicular area exposed is

$$A = a(l + h\frac{v}{w}) \tag{4}$$

Thus the perpendicular area exposed increases linearly with the speed at which you run.

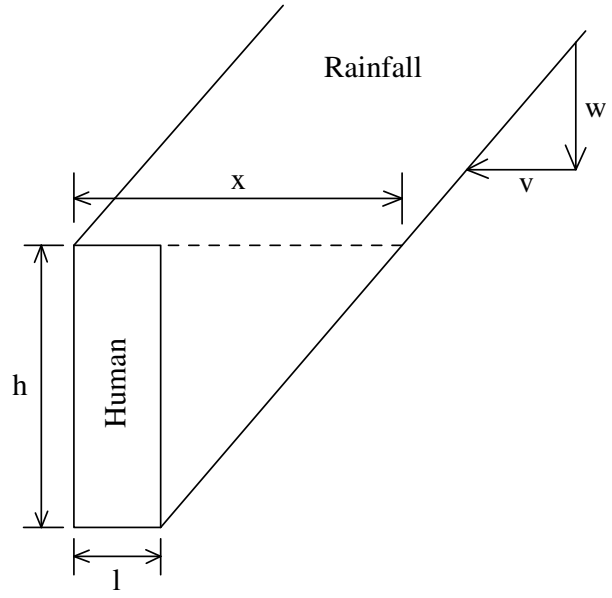

Figure 1: The perpendicular area of the human exposed to the rain when moving at velocity v is given by $A = ax$

2.4 How Wet?

Substituting our formulas (1) for the time of the journey and (4) for the perpendicular area exposed into the equation (2) for the mass of water absorbed gives us the following

$$M = \rho a(l + h\frac{v}{w})w\frac{d}{v} = M_0(1 + \frac{l}{h}\frac{w}{v}) \tag{5}$$

Where $M_0 = \rho ahd$ is the mass of water contained in the volume of the tube swept out by the human as they move from the start to the end of there journey. This represents the theoretical minimum mass of water the human will absorb and is approached as $v \longrightarrow \infty$.

The first thing we note from our formula is that M does actually decrease as we increase the speed with which the human moves. Thus running in the rain is a better option than walking. However because the effect is inversely proportional to v we have to ask whether the difference is significant for the speeds involved.

2.5 A Realistic Solution

To calculate a realistic solution to these equations we must use realistic values [1] for the variables l, h, w and v.

A typical human will have $\frac{l}{h} = 0.15$

We take the rain to be falling at a speed $w = 8ms^{-1}$

We assume that the humans speed v will fall in the range

$$1ms^{-1} < v < 8ms^{-1} \tag{6}$$

Substituting these values into equation (5) for the mass absorbed gives us the bounds

$$1.1 < \frac{M}{M_0} < 2.2 \tag{7}$$

where the lowest values of M correspond to the highest values of v.

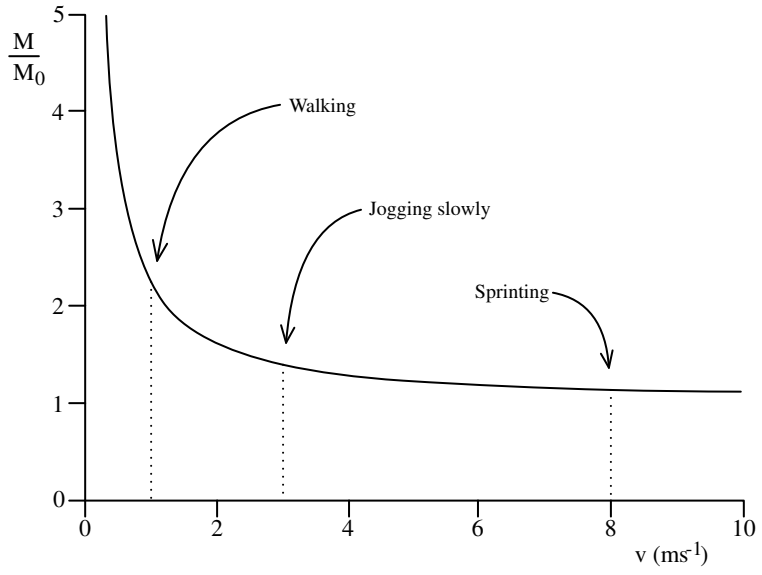

Figure 2: The mass of water absorbed as a function of v, using $\frac{l}{h} = 0.15$ and $w = 8ms^{-1}$

Thus running fast will as much as halve the amount of water you absorb. However if we consider a gentle jog speed of $3ms^{-1}$, we obtain the value $\frac{M}{M_0} = 1.4$ which is significantly less than the 2.2 for walking, and is quite

near the 1.1 of a fast run. Fig 2 shows a graph of $\frac{M}{M_0}$ against v, which reveals how it is unnecessary to run any faster than a slow jog, since the reduction in water absorption becomes negligible.

3 Future Directions

The study of human water absorption is a very active area of research. Work is currently underway in many different directions, a few of which we mention here.

One such exciting direction is the study of the effect of the wind [3]. It seems obvious that a head wind will direct more rain onto the humans surface, thus increasing the absorption. A tail wind however may either increase or decrease the absorption depending on its speed compared with that of the human. Recent results have shown that a side wind will always increase the absorption.

Also being studied are the phenomena of saturation and the rate of drying [4]. In our model we have singular behaviour at $v = 0$, corresponding to the infinite amount of water absorbed when the human remains stationary in the rain indefinitely. Saturation is expected to remove this singular behaviour. So far however analytical methods have proved intractable. Numerical solutions in this area are quite promising, and it has been shown that above a certain rain density the human does appear to become saturated.

One other related area that also deserves a mention is the study of splashes from stepping in puddles. There have been major advances in this field however to explain them here would take us well beyond the scope of this paper, the interested reader is referred to the literature [5, 6].

4 Conclusions

Get an umbrella.

References

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