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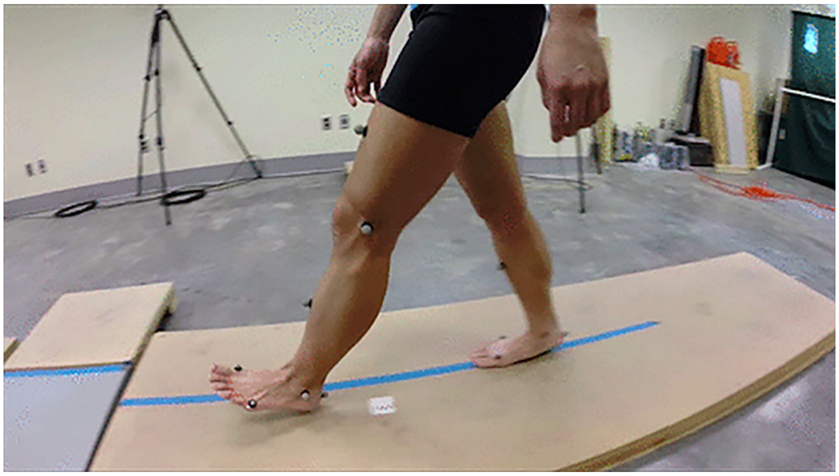
INSIDE JEB

Humans walk on virtual length legs



Volunteer walking with heel-first gait. Photo credit: James Webber.

While many of the athletes that line up for one of the planet's great marathon races will be sporting the latest high-tech footwear, an increasing number of running enthusiasts are casting aside their Nikes and Asics in favour of a more free style of running. Preferring to run barefoot, these athletes land on the balls of the foot rather than striking the ground heel first. 'I've been a barefoot runner for about 12 years', says James Webber from the University of Arizona, who explains that his passion took him to graduate school to learn about the evolution of human running. However, something bothered Webber. 'In running, people can change foot postures and it does not seem to change energetic costs very much', he says – which made him wonder: why are we so locked into landing on our heels when we walk?

Walking humans effectively move like an inverted swinging pendulum – pivoting above the foot that is in contact with the ground as we step forward – and Webber explains that when we transfer our weight forward from the heel to the toe, the centre of pressure slides across the sole of the foot. Reasoning that this could mean that the true centre of pendulum rotation is effectively several centimetres beneath the ground, Webber wondered whether our conventional flat-footed style of walking effectively lengthens the leg. If so, this could improve our efficiency and allow us to walk faster than if we walked toe-first like many other animals.

To test this theory, Webber and his thesis advisor David Raichlen set about observing what happened to walkers when they reversed their normal footfall pattern to walk like a ballet dancer – landing on the ball of the foot first before allowing the heal to touch down. Webber recruited 14 volunteers to try out the novel walk. 'It feels a little like you are walking on the catwalk', laughs Webber, who admits that it took a while for some of the volunteers to take the alternative gait seriously. But once they had got the hang of sashaying along the walkway, he was able to film them walking over speeds ranging from a gentle 0.78 m s^{-1} to a brisk 1.47 m s^{-1} before asking them to revert to their more conventional heel-first footfall pattern.

Calculating the effective leg length of the volunteers as they walked conventionally and toe-first, Webber was impressed to see that the walkers' legs were effectively 15 cm longer when the heel hit the ground first. And when he and Raichlen compared the cost of the two styles of locomotion, the toe-first walkers were having to work ~10% harder than when they landed on the heel first. Webber also asked the volunteers to walk on a treadmill as he slowly increased the speed until they had to shift up gear into a run – because it was no longer efficient to continue walking – and found that they switched to a run at lower speeds when touching down with the front of the foot first, suggesting that the toe-first walk was less efficient than conventional walking.

So, we appear to gain the mechanical benefit of longer legs when landing on the heel first while walking because weight is transferred forward along the foot during a stride, which effectively shifts the stride pivot point several centimetres beneath the sole of the foot to extend the virtual leg. And Webber suggests that our unusual running style could be a relic of our evolutionary past. Explaining that the combination of a heel-to-toe gait and a long rigid foot appears to be essential for economical walking in our ancient ancestors, Webber suspects that early humans retained the unusual posture – despite developing shorter toes to generate a stronger push off – when they took up running in pursuit of prey.

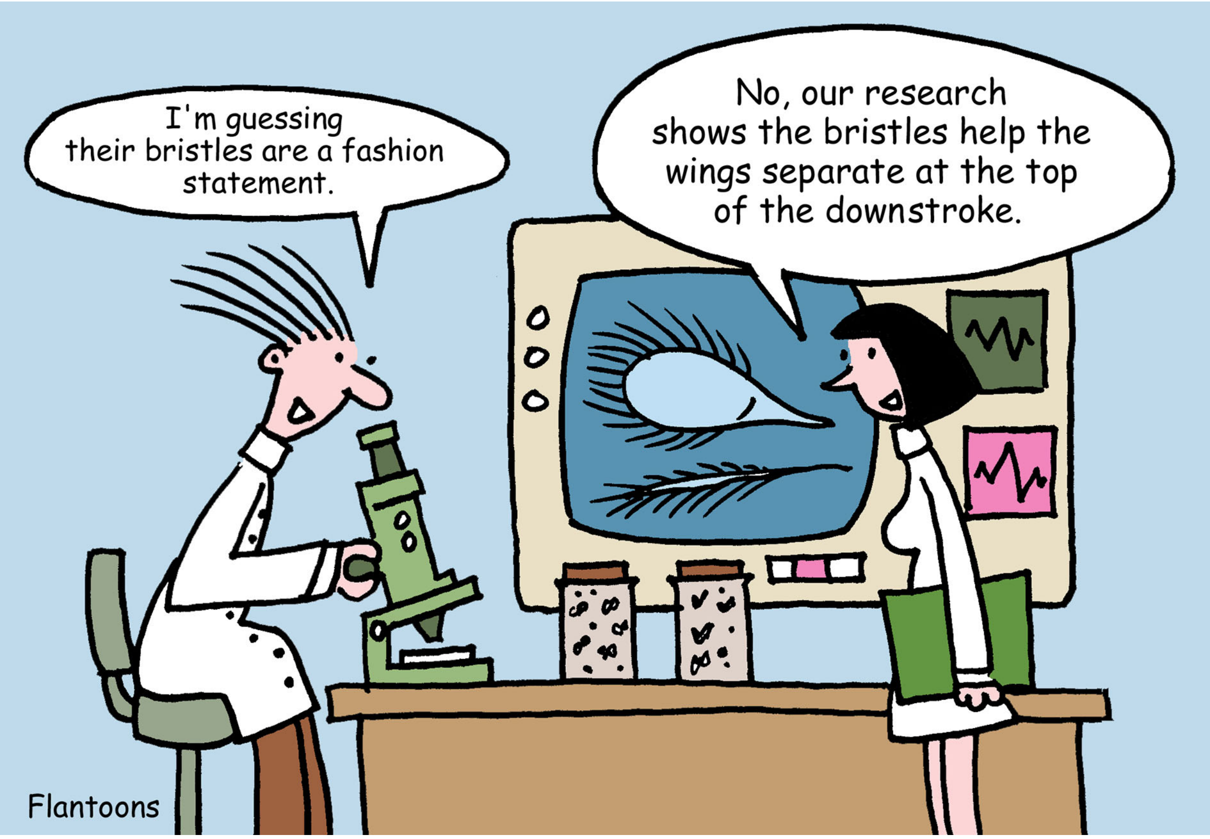
10.1242/jeb.153080

Webber, J. T. and Raichlen, D. A. (2016). The role of plantigrady and heel-strike in the mechanics and energetics of human walking with implications for the evolution of the human foot. *J. Exp. Biol.* **219**, 3729-3737.

Kathryn Knight

Inside JEB highlights the key developments in Journal of Experimental Biology. Written by science journalists, the short reports give the inside view of the science in JEB.

Bristly wings give fairyflies the edge



Fairyflies are the tiniest insects on the planet: with body lengths averaging no more than a millimetre, the minute creatures barely get noticed. However, if you were to take a closer look, you would discover that the diminutive mini-beasts also sport extraordinary fringed wings. Explaining that the lengthy bristles that line the edge of the wing could play various roles – from reducing the weight of the wing to sensing air flow – Shannon Jones and Laura Miller from the University of North Carolina at Chapel Hill, USA, decided to test the possible impact of the bristles on fairyfly flight.

Working with Jones and Miller, Young Yun and Tyson Hedrick analysed the size and distribution of the bristles around the edges of the wings of 23 different species, ranging from the minute *Kikiki huna* to the heftier *Eustochus nipponicus*, and found that the tinier insects had the most tightly packed and slender bristles, in contrast to the larger species whose bristles were sparser and chunkier. The team also noticed that the bristles made up a larger portion of the wing's surface area in the smallest flies which they say, 'supports the idea that bristles may play an important physiological or mechanical role for the smallest insects'.

Intrigued by the impact of the bristles on flight, Jones and Boyce Griffith calculated how the wings interacted with flowing air when tilted at various angles. They discovered that when the bristly wings were hardly tilted relative to the air flow, the wing produced as much force as a solid wing of the same size: the bristles may help the flies to reduce the weight of the wing without losing too much power. And when the team analysed the amount of force required to tear the wings apart when they meet together at the top of a wing beat – known as the clap and fling – they discovered that less force is required to prise bristly wings apart. They say, 'These results support the idea that bristles may offer an aerodynamic benefit during clap and fling in tiny insects', although they add that the bristles may also offer other benefits.

10.1242/jeb.153098

Jones, S. K., Yun, Y. J. J., Hedrick, T. L., Griffith, B. E. and Miller, L. A. (2016). Bristles reduce the force required to 'fling' wings apart in the smallest insects. *J. Exp. Biol.* **219**, 3759-3772.

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