Are high speed elephants running or walking?

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Most animals don't think anything of breaking into a run: they switch effortlessly from walking to a high-speed bouncing run. But what about elephants? Their sheer size makes it impossible for them to bounce up in the air at high speeds. So how are high-speed elephants moving: are they running or walking?

At a first glance, fast-moving elephants look as if they are walking, according to John Hutchinson from the Royal Veterinary College, UK. But closer analysis of elephant footfall patterns by Hutchinson suggested that speedy elephants' front legs walk while their hind legs may trot. Norman Heglund from the Université catholique de Louvain, Belgium, realised that the only way to resolve the conundrum was to measure the immense forces exerted on the animals by the ground as they move and found that elephants run in some senses, but not in others. They publish their results on 12 February 2010 in The *Journal of Experimental Biology*.

To measure these forces, Heglund had to construct and calibrate an 8m long, elephant-sized force platform from sixteen 1m2 force plates. Crating the 300kg force plates, cameras and computers in Belgium and shipping the equipment to the Thai Elephant Conservation Centre in Lampang, Thailand, Heglund, Joakim Genin, Patrick Willems, Giovanni Cavagna and Richard Lair built a reinforced concrete foundation and assembled the force platform ready to measure the enormous ground reaction forces generated by the animals.

Encouraged to move by their mahouts, 34 elephants ranging from an 870kg baby up to a 4 tonne adult moved over the force platform at speeds ranging from a 0.38m/s stroll to a 4.97m/s charge. Based on the force measurements, the Belgian team was able to reconstruct the movement of each animal's centre of mass and found that the elephant's movements are extremely economical. Consuming a minimum of 0.8J/kg/m, an elephant's cost of transport is 1/3 that of humans and 1/30 that of mice.

Heglund explains that the elephant's cost of transport is low because the animal's step frequency is higher than expected and they improve their stability by keeping an average of two feet on the ground even at high speeds, and three at lower speeds. Combining these approaches, the elephant's centre of mass bounces less than other animals', reducing the giant's cost of transport.

Next the team calculated the way that each animal recycles potential energy into kinetic energy to find out whether they run. According to Heglund, running animals continually recycle potential energy stored in tendons and muscles into bouncing kinetic energy - just like a pogo stick - while walking animals convert potential energy at the start of a stride into kinetic energy as they step forward - much like an inverted swinging pendulum. By tracking how elephants cycle potential energy into kinetic energy over the course of a stride, the team could distinguish whether the high-speed animals were running or walking.

Plotting the potential and kinetic energy of the elephants' centres of mass over the course of many strides at different speeds, the team could see that the elephants were walking like an inverted pendulum at low speeds, but as they moved faster, the kinetic and potential energy plots shifted to look like those of runners. However, when the team analysed the movements of the elephant's centre of mass, they could see that it almost maintained a constant level as the animal shifted its weight from one side

to the other, but bobbed down and up like a runner's during the second half of the stride.

So the elephants were running by one measure but not by another and it seems that the forelimbs trot while the hind limbs walk at higher speeds. 'High-speed locomotion in an elephant doesn't fall nicely into a classic category like a run or a trot. It really depends on your definition of "run",' says Heglund.

More information: Genin, J. G., Willems, P. A., Cavagna, G. A., Lair, R. and Heglund, N. C. (2010). Biomechanics of locomotion in Asian elephants. J. Exp. Biol. 213, 694-706. http://jeb.biologists.org

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