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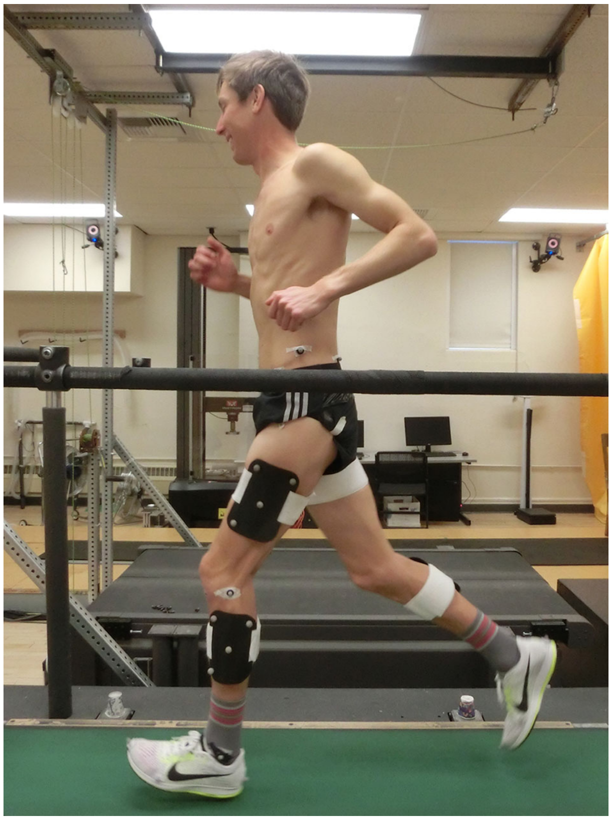
INSIDE JEB

Muscles make the difference when determining runners' energy consumption



An elite athlete running on a treadmill. Photo credit: Shalaya Kipp.

Efficiency is the secret to top athletic success. Squandered energy can cost valuable milliseconds in races. 'Understanding what determines the rate of metabolic energy expenditure is of interest to athletes, coaches and sports scientists', says Shalaya Kipp, from the University of Colorado, Boulder, USA. Although previous attempts to identify the factors that determine how much energy runners use had been reasonably successful, none had completely accounted for the total energy expenditure. For example, one equation – relating energy consumption to the length of time that a runner's foot is in contact with the ground, when it can generate force – explains 70% of the runner's increase in metabolic energy consumption as they ramp up their speed, but it wasn't clear how other factors might contribute.

PI Rodger Kram and Kipp decided to include an additional factor in their calculations. Knowing that energy consumption rises as the volume of muscle that is working increases, the duo wondered whether this volume increase could account for the increasing metabolic rate as runners shift up through the gears. The duo decided to measure how much energy athletes consumed and calculate how much muscle they recruited while running at different speeds to find out whether adding in the muscle factor produced a more accurate prediction of how much energy runners might use at different speeds.

'We needed high-calibre runners', says Kipp, who explains that the athletes had to be happy to run 5.22-minute miles consistently without getting out of breath so that she and her colleagues could accurately determine their metabolic rates based on their oxygen consumption. 'Fortunately Boulder Colorado is known as a Mecca for distance runners', says Kipp who is a member of the elite community and recruited 10 volunteers through her local connections.

Inviting the athletes into the lab, Kipp, Kram and their colleague Alena Grabowski attached reflective markers to their limbs and filmed them as they ran at speeds ranging from 8 to 18 km h^{-1} on a treadmill while measuring the amount of oxygen that the runners consumed, the CO_2 produced and the force they exerted on the ground during each stride. Kipp then analysed the movements of each runner, calculating how long each foot was in contact with the ground (to determine the rate of muscle force development) and the total volume of actively contracting leg muscle as the athletes ran at different paces. Impressively, the volume of leg muscle used by the runners increased by over 50% over the full range of speeds. And when the team calculated the metabolic rates of the runners – based on an equation linking the volume of muscle that they were using at each speed and the amount of time their feet were in contact with the ground during a stride – the values were remarkably similar to the measured metabolic rates (within 98%) that the team determined from the runners' oxygen consumption.

'We found that the rate of force production and active leg muscle volume together almost completely account for the metabolic requirements of human running', says Kipp, and she hopes to find out how well other animals conform to the new paradigm linking muscle to running efficiency.

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Kipp, S., Grabowski, A. M. and Kram, R. (2018). What determines the metabolic cost of human running across a wide range of velocities? *J. Exp. Biol.* **221**, jeb184218.

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