Pound for pound: Working out how obesity influences the energetics of walking

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Submitted 8 April 2009; accepted in final form 8 April 2009

Childhood and adult obesity are both serious health problems that are catalyzed by inadequate physical activity and the resulting chronic energy imbalance. For most people, walking consumes more metabolic energy than any other daily activity. Thus it is important to understand the energetic cost of walking for obese persons. Recently, physiologists have quantified the greater metabolic cost of walking by obese children and adults, and when the rates of energy consumption are expressed per kilogram of body mass, they are only modestly greater for obese vs. lean individuals.

One could argue that this relatively small increase in energy consumption is surprising because biomechanically there are many reasons to expect that the cost of walking would be dramatically greater for obese individuals. Obese persons of course have heavier legs, walk with greater step width (2, 12), and have greater lateral leg swing (hip circumduction) (12). The extra cost of those factors can be inferred from experiments that attached lead weights to the legs of lean persons (3) and others that enforced wide steps (9) and lateral leg swing. All told, we would predict that a 50-kg lean person loaded with lead on their thighs to match the fat mass carried on the thighs of a 100-kg obese person, who walked with 30% wider steps and with an equivalent amount of circumduction would consume 80% more metabolic energy! One explanation for why obese persons do not actually use that much more energy could be that, as a person becomes obese, they learn to walk in a way that reduces the mechanical work required to lift, lower, accelerate, and decelerate their center of mass. That possibility is suggested by the wonderful discovery that African women can carry loads atop their heads of 20% of their body weight without additional metabolic cost. By some reckoning, that feat is accomplished by more skillful exchange of kinetic and gravitational potential energy so as to avoid the need for additional mechanical work (8). This exchange of mechanical energy is termed the inverted pendulum mechanism. Three different groups of biomechanists have recently tried to understand whether obese walkers also minimize the mechanical work of walking via the inverted pendulum mechanism.

In this issue of the Journal of Applied Physiology, a comprehensive study by Peyrot et al. (11) reports that, compared with their lean peers, obese adolescent boys and girls consumed 25% more metabolic energy per kilogram body mass to walk a given distance (J·kg⁻¹·m⁻²). That figure is the average for four different speeds; the difference diminished to just 15% at a typical walking speed (1.5 m/s). The metabolic cost of walking was calculated as the total rate of energy consumption minus the metabolic cost of standing (i.e., they are “net” values). Although debatable, net values eliminate differences in the baseline metabolic rate and thus focus on the metabolic cost of walking itself. To try to uncover a biomechanical reason for the only slightly more expensive walking, Peyrot et al. attached an inertial accelerometer-gyroscope device to subjects near their body center of mass. With careful calibration, they used these newly developed devices to track the three-dimensional accelerations of the center of mass. Subsequently, the acceleration data were numerically integrated to determine the velocity and displacements of the center of mass and thus allow the calculation of the mechanical work performed. The authors hypothesized that, compared with lean controls, the obese adolescents would perform a disproportionately greater amount of work due to greater medio-lateral movements. However, despite two times greater lateral displacements of the center of mass with each step, the total mechanical work performed on the center of mass was not different. That was in part because medio-lateral work comprises only a small fraction of total work performed on the center of mass. Bottom line is, the calculated mechanical work did not explain the greater metabolic cost of walking for obese adolescents.

A similar story has recently emerged for obese adults. In 2006, we were surprised to find that obese women and men have net metabolic costs of walking that are only 10–12% greater than lean adults (1). Then, in the February 2009 issue of Medicine and Science in Sports and Exercise, Malatesta et al. (10) measured the mechanical work performed by obese and lean adults while walking at their respective preferred speeds. They optically tracked the movements of a marker placed near the center of mass and used the classic combined limbs method of calculating work (5). Just like Peyrot et al., the Malatesta group found no differences in the mechanical work (J·kg⁻¹·m⁻¹). Thus the idea that obese people walk with the unique grace of African women head-load carriers was dispelled.

Faced with similarly enigmatic results, both Peyrot et al. and Malatesta et al. suggested a methodological problem. Neither group used the forceplatform-based individual limbs method (ILM) technique (9). Thus they could not detect possible differences in the mechanical work that is “wasted” when the leading and trailing legs fight each other during the double support phase of walking (when both feet are on the ground). But in March, our own group presented data that quashed that idea as well (4). Using a three-dimensional ILM approach, we also found no differences in the mechanical work performed (J·kg⁻¹·m⁻¹) between obese and lean subjects walking across a range of speeds.
What explanations remain viable? One possibility is that obese persons perform a typical amount of mechanical work but somehow reduce the cost of supporting body weight. Devita and Hortobagyi (6) found that a mixed group of moderate and extremely obese persons walked with straighter knees, which would reduce the muscular forces required. However, we did not corroborate that finding in a group limited to moderately obese persons (2). Another possibility is that obese persons somehow gradually adapt as their legs grow more massive so that the cost of leg swinging is mollified. Finally, one could argue that perhaps we should actually expect only a slightly greater energy consumption for obese walking. When lean adults walk with lead weights wrapped around their waists (i.e., acutely simulating obesity), the energy consumption per kilogram total mass (body plus load) is similar to that reported for obese adults (3). This suggests that total mass is the primary determinant of metabolic cost. Further support for this idea is that sagittal plane leg swing is a relatively small component (~10%) of the metabolic cost of walking (7), and even with heavier legs that swing wider, we should only expect this to moderately increase the cost of walking.

Before closing, we do not wish to mislead a casual reader into thinking that obese persons must walk just as far to burn an absolute amount of energy (calories). Indeed not. Compared with a lean 50-kg person, a 100-kg obese person requires more than twice as much energy (or twice as many calories) to walk a kilometer (or mile). The problem is that we do not yet understand why it does not cost even more.

REFERENCES