Soft tissue work during walking: An energy conserving mechanism for obese adults?

Xiao-Yu Fu, Karl E. Zelik, Wayne J. Board, Raymond C. Browning, Arthur D. Kuo
University of Michigan and Colorado State University

Obesity is a significant public health problem that is due, at least in part, to greater energy intake than expenditure. Studies have indicated that the mass-specific **metabolic cost of walking for obese compared to non-obese individuals is only modestly greater** (10-20%). When **non-obese individuals simulate obese gait via added mass and altered step width, they expend 80% more metabolic energy than obese individuals** [1]. To date, an explanation for the relatively good walking economy of obese adults has proven elusive. The determinants of the difference in obese will aid in developing a more comprehensive explanation of the factors in the energetic costs of walking.

The energetic cost of obese gait may be estimated from contributions for swinging the legs and moving the body center of mass. Obese individuals spend more time in stance and double support than non-obese individuals but have a similar stride frequency, implying that they must swing their heavier legs somewhat more rapidly [5]. But the associated cost, as estimated from non-obese walking with added leg weights, does not predict the cost of obese gait. Another possible contribution is from moving the body center of mass, quantified by the work (W_{COM}) performed on it by the individual limbs. Estimates for walking by obese persons show no differences in the mass-normalized W_{COM} between obese and lean individuals [2][3][4], suggesting the total performed COM work does not explain the metabolic difference. Conventional measures appear not to capture the salient difference between obese and non-obese gait.

Because COM **work can be performed both actively by muscles and passively by soft tissues, one possible explanation for the metabolic economy discrepancy is that obese subjects perform more of the work passively.** We examined the difference in summed joint power (sum of all three planes of ankle, knee, and hip power) and center of mass work rate (three dimensional dot-product of center of mass velocity with each limb's ground reaction force), and the difference in work generated by each through integrating over each phase of the gait cycle, to analyze the potential contributions of soft tissue work [6] to the metabolic cost of walking. We compared 6 obese and 10 non-obese adult individuals walking on split-belt treadmills at 1.25 m/s with forces collected by force plates under each belt and kinematic data collected by passive-marker motion capture systems. We **hypothesized that obese subjects would have a greater difference of summed joint work to center of mass work during the early phases of stance (collision and rebound) after heel-strike, suggesting greater soft tissue contributions.**

We observed a small difference in COM work between the obese and non-obese participants. Obese participants performed slightly more work per step, in part because they walked with slightly greater step lengths. We also observed differences in summed joint work between the two groups. Examining both work measurements over a stride, there appeared to be little difference during pre-load and push-off phases. Most notable was the rebound phase, where the net joint work was negative in obese subjects, but positive in non-obese subjects [Fig 2].

The work performed by soft tissues appears to be much greater in obese individuals. This is indicated by the increased difference of summed joint work to center of mass work after heel-strike in obese subjects, particularly during collision rebound, suggests that. Specifically **during rebound, there is a 3 fold increase in positive non-joint (soft tissue) work in obese compared to non-obese participants**. Our results suggest that **an elastic rebound of soft tissues may reduce the positive work required by muscles. This elastic rebound may enable obese individuals to walk more economically**.

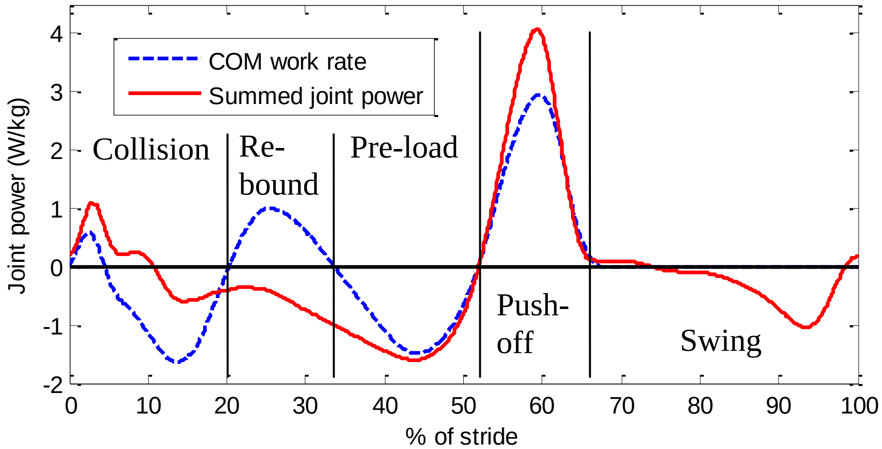

Fig 1. A sample obese subject's mean single-limb center of mass work rate and summed joint power vs time. Phases of gait are determined approximately by zero-crossings of the COM work rate. Work is computed by integrating under the curves.

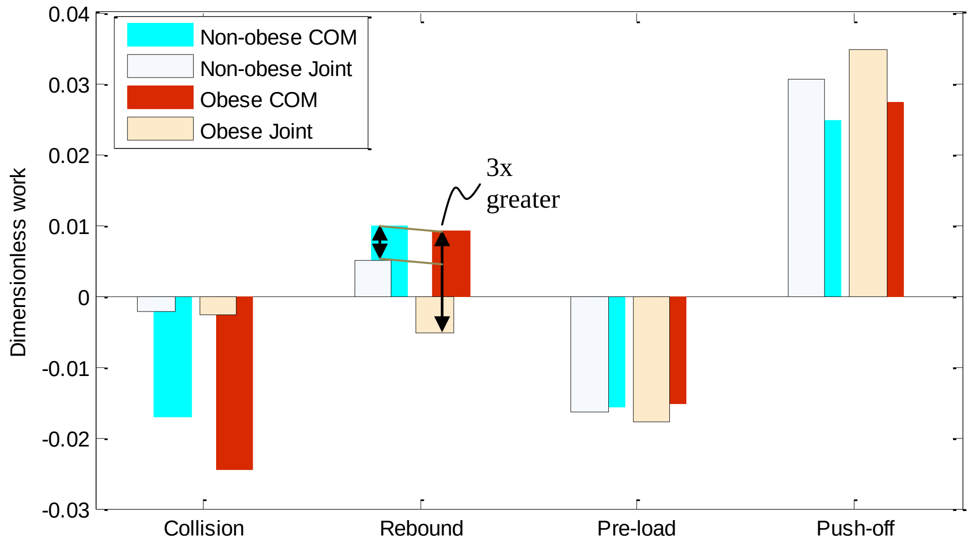

Fig 2. Total dimensionless work during each phase of stance from summed joint work and center of mass work in obese and non-obese subjects. The difference between joint work and center of mass work during rebound is notably 3 times greater in obese subjects compared to non-obese subjects.

Preferred format: Talk

Keywords: obesity, energetics, soft-tissue

[1] Browning RC and Kram R. Pound for pound: Working out how obesity influences the energetic of walking. *J Appl Physiol* 106: 1755-1756, 2009.
[2] Peyrot N, Thivel D, Isacco L, Morin JB, Duche P, and Belli A. Do gait mechanical parameters explain the higher metabolic cost of walking in obese adolescents? *J Appl Physiol* 106: 1763-1770.
[3] Malatesta D, Vismara L, Menegoni F, Galli M, Romei M, Capodaglio P. Mechanical external work and recovery at preferred walking speed in obese subjects. *Med Sci Sports Exerc* 41: 426–434, 2009.
[4] Browning RC, McGowan CP, and Kram R. Obesity does not increase external mechanical work per kilogram body mass during walking. *J Biomech* 42(14): 2273–2278, 2009.
[5] Błaszczyk JW, Plewa M, Cieślinska-Swider J, Bacik B, Zahorska-Markiewicz B, and Markiewicz A. Impact of excess body weight on walking at the preferred speed. *Acta Neurobiol Exp (Wars)* 71(4):528-40, 2011.
[6] Zelik KE and Kuo AD. Human walking isn't all hard work: evidence of soft tissue contributions to energy dissipation and return. *J. Exper Bio* 213:4257-4264, 2010