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RELATIONSHIP BETWEEN CENTER OF MASS VERTICAL MOTION AND METABOLIC COST IN WALKING

According to Saunders et al. [1], walking with a flat center of mass trajectory reduces the muscular work required to lift the body and, consequently, reduces the metabolic cost of locomotion.

According to the alternative view, the vertical movements of the center of mass allow the exchange of mechanical energy and thereby reduce mechanical work required to move the center of mass and the metabolic cost of walking [2].

According to the inverted pendulum model, the out-of-phase fluctuations in gravitational potential energy and kinetic energy represent a continuous exchange of mechanical energy.

The two divergent views regarding the relationship between center of mass vertical motion and metabolic cost have not yet been reconciled.

We hypothesized that metabolic cost would not decrease when humans walk with a flattened center of mass trajectory. To test our hypotheses, we examined metabolic cost, mechanical energy exchange, and net external work for humans walking with small vertical movements of the center of mass compared with walking with normal center of mass movements.

MATERIALS AND METHODS

Experimental design. Kinetic and metabolic data were collected for three healthy adult humans (men) without any known orthopedic, neurological, or cardiovascular disease. The subjects had an average age of 23.6 yr (SD 1.6), mass of 72.5 kg (SD 5.7), and height of 1.75 m (SD 0.05). Before the experiment, all subjects gave their written, informed consent.

Each subject participated in two sessions including a practice session and one testing session. In all sessions, subjects walked on a custom-built motorized treadmill.

Metabolic cost. We measured the rates of O2 consumption and carbon dioxide production using open-circuit indirect calorimetry («METAMAX – 3B», “Cortex”, Germany).

Kinematics. We measured sagittal plane kinematics of the right lower limb using high-speed video (150 fields/s, “Opus”, “Qualisys”, Sweden).

From the position data, we calculated the hip, knee, and ankle angles during the stance phase of walking. Each joint angle was defined as the acute angle between adjacent segments. We determined the average angle and minimum angle for each joint during the stance phase. We focused on the stance phase because stance limb action is the primary determinant of the motion of the center of mass.

RESULTS

Our results show that minimizing the vertical motion of the center of mass doubles metabolic cost but does not affect net external work in human walking. Our findings emphasize that net external work is not the main determinant of the metabolic cost of walking and suggest that the cost of generating muscle force to support body weight plays a key role. These findings have clinical implications for therapies aiming to improve walking economy in patients with gait disorders that affect center of mass motion and metabolic cost such as hip joint replacement, lower limb amputation, stroke, and cerebral palsy. Indeed, Detrembler et al. [3] suggest impaired inverted pendulum recovery of mechanical energy is an important factor in the increased metabolic cost during stroke-induced hemiparetic walking. However, based on Saunders et al. [1], some literature suggests that patients with gait disorders should be trained to walk with little vertical motion of the trunk to reduce metabolic cost [4].

Conclusion.

Our findings suggest that maintaining normal levels of vertical center of mass motion and an extended stance limb are important factors in reducing the metabolic cost of walking.

References.

1. Saunders JB, Inman VT, and Eberhart HD. The major determinants in normal and pathological gait. J Bone Joint Surg Am 35: 543–558, 1953.

2. Cavagna GA and Kaneko M. Mechanical work and efficiency in level walking and running. J Physiol 268: 647–681, 1977.

3. Detrembleur C, Dierick F, Stoquart G, Chantraine F, and Lejeune T. Energy cost, mechanical work, and efficiency of hemiparetic walking. Gait Post 18: 47–55, 2003.

4. Esquenazi A and Talaty M. Normal and pathological gait analysis. In: Physical Medicine and Rehabilitation: the Complete Approach, edited by Grabois M, Garrison SJ, Hart KA, and Lehmkuhl DL. Oxford, UK: Blackwell, 2000, p. 242–262.