The Effects of Velocity and Weight Support on Metabolic Power and Ground Reaction Forces During Walking

[1,2]Alena M. Grabowski
[1]University of Colorado, Boulder, [2]Massachusetts Institute of Technology
email: alenag@mit.edu, web: http://web.media.mit.edu/~alenag

SUMMARY

Velocity and body weight (BW) support distinctly affect metabolic cost and peak ground reaction forces during human walking. At faster speeds, greater metabolic power is required and peak ground reaction forces (GRF) increase. Weight supported walking results in attenuated peak GRFs, and demands less metabolic power than normal weight walking. We utilized a recently developed device (G-trainer) that uses positive air pressure around the lower body to support body weight during treadmill walking and quantified the separate and combined effects of velocity and weight support on kinematics, GRFs, and metabolic power. We found that subjects' peak GRFs were less, yet they required the same metabolic power at faster speeds with BW support compared to slower speeds without weight support.

INTRODUCTION

Both generating force to support body weight and performing work on the center of mass (COM) during walking incur metabolic costs due to the action of the muscles [1,2]. During stance, muscles generate a nearly isometric force to prevent the leg from collapsing and to support the weight of the body. During double support, work is performed on the COM to redirect and reaccelerate the COM upward and forward.

Prior studies have examined the effects of velocity and BW support on the biomechanics of walking, but the combined effects on the metabolic costs have not been systematically investigated. Thus, we used a lower body positive pressure apparatus (G-trainer, Alter-G, Inc., Fig.1) to quantify the resulting metabolic power and peak vertical GRFs. We hypothesized that compared to walking without weight support at a slower speed, walking with weight support at a faster speed would demand the same metabolic power, yet result in lower peak vertical GRFs.

METHODS

Ten healthy subjects volunteered [5 M, 5 F, 66.4 kg (SD 12.1)] and gave informed written consent. Subjects walked on a single-belt force-measuring treadmill (FTM) at normal weight and with weight support (Fig. 1). We measured rates of oxygen consumption and carbon dioxide production using open-circuit respirometry, stance phase duration using foot-switches, and individual leg GRFs using the technique of Davis & Cavanagh [3] at 5 levels of BW support (0.25, 0.50, 0.75, 0.85 & 1.0 BW) and 3 velocities (1.0, 1.25, & 1.5 m/s).

RESULTS AND DISCUSSION

As we supported body weight, net metabolic power decreased linearly, but in less than direct proportion to weight support (Fig. 2). Our results show greater reductions in metabolic cost compared to previous simulated reduced gravity studies [2]. It is likely that our apparatus not only supported subjects' body weight, but also provided some stability in the anterior/posterior and lateral directions.

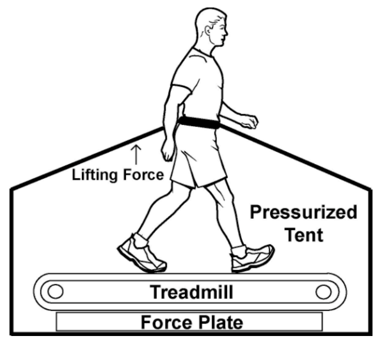

Figure 1: Lower-body positive-pressure device.

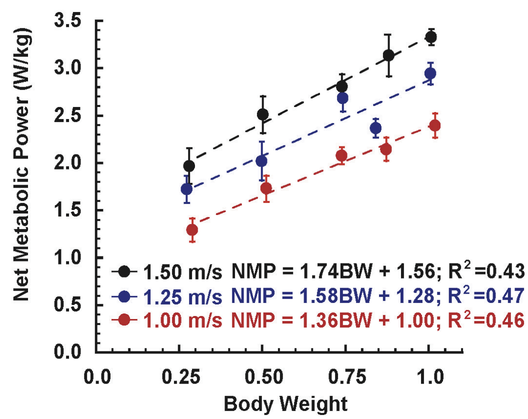

Figure 2: Net metabolic power at different fractions of body weight. Values are means +/- SEM. Dashed lines represent linear least squares regressions.

At equivalent metabolic demands, peak GRFs were attenuated at faster speeds with weight support compared to slower speeds without weight support. For example, at 1.25 m/s & 1.0 BW, the first and second peak vertical GRFs were 731.7 N and 741.9 N, whereas at 1.5 m/s & 0.75BW, peak vertical GRFs were 16% and 26% lower (615.5 and 547.8 N). Also, the weight support provided by the G-trainer allowed subjects to retain the stance-phase timing of normal weight walking and did not apply resistive forces such as those experienced in water immersion therapy, thus this device could be very beneficial as a rehabilitation/post-surgery tool.

REFERENCES

1. Donelan, JM, et al. *J Exp. Biol.* **205,** 3717-3727, 2002.
2. Grabowski, AM, et al. *J Appl Phys.* **98**, 579-583, 2005.
3. Davis, BL & Cavanagh, PR. *J Biom.* **26,** 593-597, 1993.