INDEPENDENT EFFECTS OF BODY WEIGHT AND MASS ON THE METABOLIC COST OF RUNNING

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INTRODUCTION

The metabolic cost of running is substantial, despite savings from elastic energy storage and return. Previous studies suggest that the major determinants of the metabolic cost of running are generating vertical force to support body weight (Kram and Taylor, 1990) and horizontal forces to brake and propel body mass (Chang and Kram, 1999). However, the independent metabolic costs of supporting body weight and braking/propelling body mass have not been previously measured in running.

We hypothesized that supporting body weight would proportionally decrease metabolic power demand (as per Farley and McMahon, 1992), adding mass and weight would proportionally increase metabolic power demand, and adding mass alone would not substantially affect metabolic power demand.

METHODS

10 recreational human runners (6 M, 4 F, mass: 63.3 ± 9.8 kg, mean ± s.d.) volunteered. Subjects performed a standing trial and 10 running trials at 3 m/s on a force-measuring treadmill. Trials were 7 minutes long with 5 minutes rest between trials. Subjects ran normally (100% M & 100% BW; M = mass, BW = body weight), at 3 levels of weight support (100% M & 75, 50, 25% BW), with added mass and weight (110, 120, 130% M & BW), and with added mass alone (110, 120, 130% M at 100% BW).

We measured rates of oxygen consumption and carbon dioxide production during minutes 4-6 of each trial and calculated net (gross – standing) metabolic power (Brockway, 1987). We measured ground reaction forces (GRFs) at 1000 Hz during 10 strides.

We reduced body weight using a harness system (Fig. 1), increased mass and weight using lead worn about the waist, and increased mass alone using a combination of reduced weight and added load as described by Grabowski et al. (2005).

We used repeated measures ANOVA with Tukey HSD follow-up tests when warranted ($P < 0.05$).

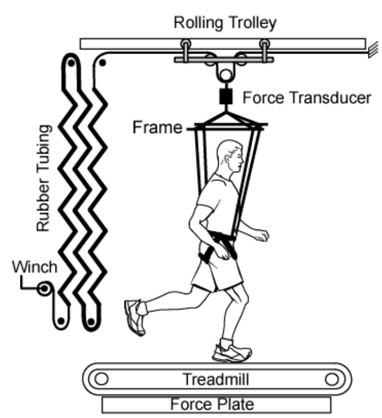

Figure 1. Weight support system

RESULTS AND DISCUSSION

Net metabolic power decreased in less than direct proportion to weight support. When subjects ran at 75% of normal body weight, net metabolic power decreased by 19 ± 1.7% (mean ± s.e.m.). At 50 and 25% of normal body weight, net metabolic power decreased by 38 ± 2.1% and 55 ± 2.7%, respectively (Fig. 2). By extrapolating the line shown in Fig. 2 ($y = 0.73x + 26.18$; $R^2 = 0.999$) to zero weight, the intercept indicates a 74% reduction in metabolic power suggesting that weight support comprises 74% of the net cost of normal running. This estimate supports the idea that muscular force generation acting in opposition to gravity is the primary determinant of the metabolic cost of running (Kram and Taylor, 1990; Taylor, 1994).

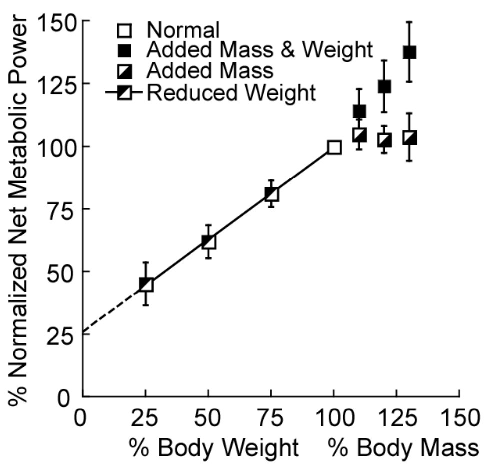

Figure 2. Means (n=10) +/- s.e.m.

Further, our metabolic data closely parallel our force data for running with weight support (Fig. 3). Net metabolic rate shows a substantial linear decrease that is similar to vertical and horizontal impulses.

Net metabolic power increased in slightly more than direct proportion to added load (added mass and weight). When subjects ran at 110% of normal body mass and weight, net metabolic power increased by 14 ± 2.7% of normal running. At 120 and 130% of normal body mass and weight, net metabolic power increased by 24 ± 3.2 and 38 ± 3.8%, respectively (Fig. 2).

Net metabolic power was not substantially different from normal running with added mass alone (Fig. 2). Runners loaded with mass alone did not generate greater vertical or horizontal impulses than normal running. Thus, adding mass alone was not an effective method for determining the cost attributable to braking/propelling body mass.

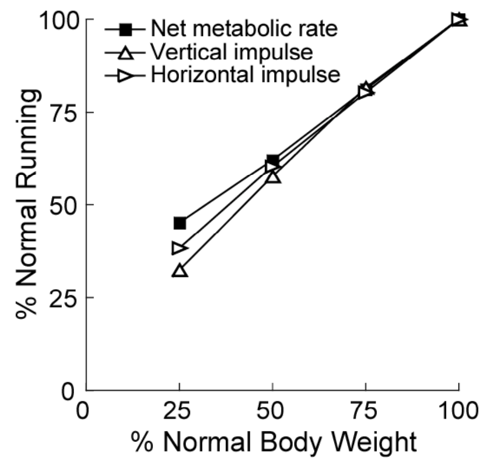

Figure 3. Means (n=10)

SUMMARY/CONCLUSIONS

Our results show that generating force to support body weight is the primary determinant of the metabolic cost of running. We deduce that the net metabolic cost to support body weight is about 74% of the total net cost of running.

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