ENERGETICS OF LOW SPEED RUNNING

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INTRODUCTION

The metabolic cost ($\dot{V}O_2$) of walking a given distance is minimized at a speed of approximately 1.25 $m \cdot s^{-1}$ while the metabolic cost of running a unit distance is essentially independent of speed (Cavagna et al., 1976; Hreljac, 1993; Margaria et al., 1963). As a result, energy-speed curves for running are generally depicted as being linear with a slope of close to zero. Energetic cost-speed curves for running are generally determined by having subjects run at a variety of speeds greater than a subject's preferred transition speed (PTS) while monitoring $\dot{V}O_2$. A curve (line) is then fit to the data before extrapolating the curve to lower speeds. The intersection of the energy-speed curve for walking (curvilinear) and running (linear) is considered to be the energetically optimal transition speed (EOTS), occurring at a speed of about 2.3 $m \cdot s^{-1}$ (Hreljac, 1993). The PTS occurs at a significantly lower speed than the EOTS (Brisswalter et al., 1996; Hreljac, 1993; Minetti et al., 1994). Since the energetic cost per unit distance approaches infinity as running speed approaches zero, it is logical to assume that the energy-speed relationship at low running speeds (below the PTS) would be non-linear. The purpose of this study was to determine whether energy-speed data during running conform better to a curvilinear (quadratic) or a linear model, and to determine the effect of model choice on the calculation of EOTS.

METHODS

Twelve young, healthy subjects (6 males, 6 females) were accommodated to treadmill locomotion prior to determination of their walk-run, and run-walk transition speeds. Each transition speed was found three times in random order, then averaged to give an overall PTS, as described in earlier studies (Brisswalter et al., 1996; Hreljac, 1993, 1995). On a day following this procedure, $\dot{V}O_2$ data were collected as subjects ran at speeds of 60, 75, 90, 100, and 120% of the PTS, and walked at 70, 80, 90, 100, and 110% of the PTS. Exercise $\dot{V}O_2$ for each of the randomly ordered conditions was found by subtracting standing $\dot{V}O_2$ values from gross $\dot{V}O_2$. All $\dot{V}O_2$ data were then normalized to body mass and speed. Energy-speed curves were fit (all subjects combined) to the normalized data points for both walking and running with speed (in units of % PTS) along the abscissa and $\dot{V}O_2$ (units of $ml \cdot kg^{-1} \cdot km^{-1}$) along the ordinate . Both linear and quadratic models were tested for each gait using a least squares regression method.

RESULTS AND DISCUSSION

At the PTS (1.99 ± 0.12 $m \cdot s^{-1}$), the energetic cost was significantly greater during running ($\dot{V}O_2 = 155.1 \pm 14.0$ $ml \cdot kg^{-1} \cdot km^{-1}$) than walking ($\dot{V}O_2 = 132.7 \pm 18.9$ $ml \cdot kg^{-1} \cdot km^{-1}$). A quadratic model fit the data better than a linear model for both walking ($r^2 = 1.00$) and running ($r^2 = 0.94$) conditions. Minimum values of $\dot{V}O_2$ for the fitted curves occurred at 61.6% of PTS, and 96.2% of the PTS during walking and running, respectively. The curves intersected (EOTS) at a speed of 110% of the PTS. The regression plots of the energy-speed relationships for each condition are illustrated in Figure 1.

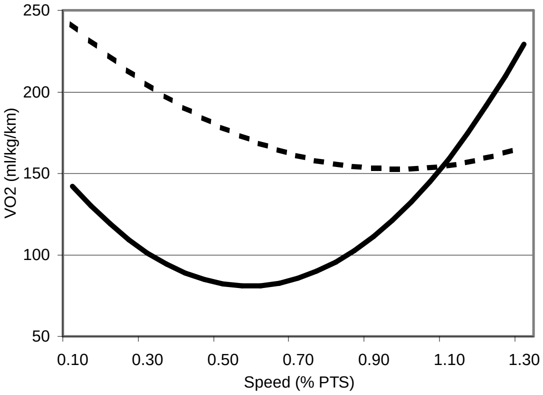

Figure 1: Relationship between $\dot{V}O_2$ per unit distance and speed (as a % of PTS) for walking (—) and running (- - -).

In this study, the speed of the minimum $\dot{V}O_2$ during walking (1.23 m· s^{-1}) was close to speeds previously reported (Cavagna et al., 1976; Hreljac, 1993; Margaria et al., 1963), while the minimum $\dot{V}O_2$ during running occurred at a speed near the PTS. The regression equation relating the $\dot{V}O_2$ to walking speed could be fit almost perfectly ($r^2 = 1.00$) to a quadratic model (Fig. 1). A curvilinear (quadratic) model ($r^2 = 0.94$) was found to represent the energy-speed data for running better than a linear model ($r^2 = 0.29$) at the low speeds tested. This relationship would likely be found only when very low running speeds are tested. The minimum $\dot{V}O_2$ of the best fitting curve during running occurred at a speed of 1.92 m· s^{-1} (96.2% of PTS) which is lower than speeds that have generally been tested by other researchers who have examined the relationship between $\dot{V}O_2$ and running speed.

The EOTS calculated in this study was not affected by running model choice, and was in agreement with prior studies (2.20 vs. 2.24 m· s^{-1}). The linear model calculated for running exhibited a negative slope, and was a poor fit. In previous studies (Hreljac, 1993; Minetti et al., 1994), running curves (lines) were depicted with slight positive or zero slopes.

SUMMARY

Combining evidence from previous studies with the results of the present study, it appears that the true energy-speed curve for running is linear (and relatively constant) for most mid-range speeds, but increases in a curvilinear fashion when running speeds are at the extreme low and high ranges. The EOTS was not affected by the choice of regression model used during running, which helps to validate previously reported results.

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