

LOWER EXTREMITY MECHANICAL WORK EXPLAINS INTERINDIVIDUAL VARIABILITY OF RUNNING ECONOMY

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INTRODUCTION

The metabolic cost of running has been linked to the cost of supporting one's mass and the time course of generating force during stance (Kram, 2000). Data from various animal species and speeds of locomotion support this claim (Kram & Taylor, 1990). Several researchers suggest that the mechanical work done by muscles is strongly tied to the metabolic cost of walking (e.g., Umberger & Martin, 2007). The work of DeVita et al. (2006) suggested that level walking and running result in a bias or "overproduction" of positive mechanical work by the musculature of the lower extremity in order to overcome dissipation by other tissues. For runners, they reported 8% more total positive work than negative work. Taken collectively, the aforementioned research points to the importance of the stance phase of locomotion and the mechanical power generated and dissipated in the lower extremity as potential determinants of metabolic energy cost. In the present study, correlations between running economy (RE; the metabolic cost at a given speed) and the positive and negative mechanical work at lower extremity joints were examined. It was hypothesized that the dominance of positive work during stance, especially at the hip and ankle, would be positively correlated to RE. Correlations between RE and mechanical energy dissipation (i.e., negative work) at each lower extremity joint were also investigated, but no specific hypotheses were formulated.

METHODS AND PROCEDURES

Sixteen well-trained men (mean $\text{VO}_{2\text{max}} = 62.2 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) performed treadmill running for determination of RE and overground running for which biomechanical measures were determined (running speed = $3.35 \text{ m}\cdot\text{s}^{-1}$). A single video camera (60 Hz) recorded a sagittal-plane view of runners as they contacted an AMTI force platform (480 Hz) with their right leg. Using coordinate data from a motion analysis system (Vicon Motus), ground reaction force data, and an inverse dynamics analysis, net joint moments were calculated for the ankle, knee, and hip during ground contact. Mechanical power was calculated as the product of net joint moment and angular velocity at each joint. Mechanical work was then quantified by integrating the power-time curves. Resulting positive and negative work values at the ankle, knee, and hip were correlated with RE.

RESULTS

Scatterplots of RE and positive and negative work values, along with correlation coefficients, are shown in Figure 1. As hypothesized, higher RE was associated with greater positive work at the hip and ankle. In addition to expectations, more economical runners (lower RE) exhibited greater negative work at the hip, greater positive work at the knee and less negative work at the ankle.

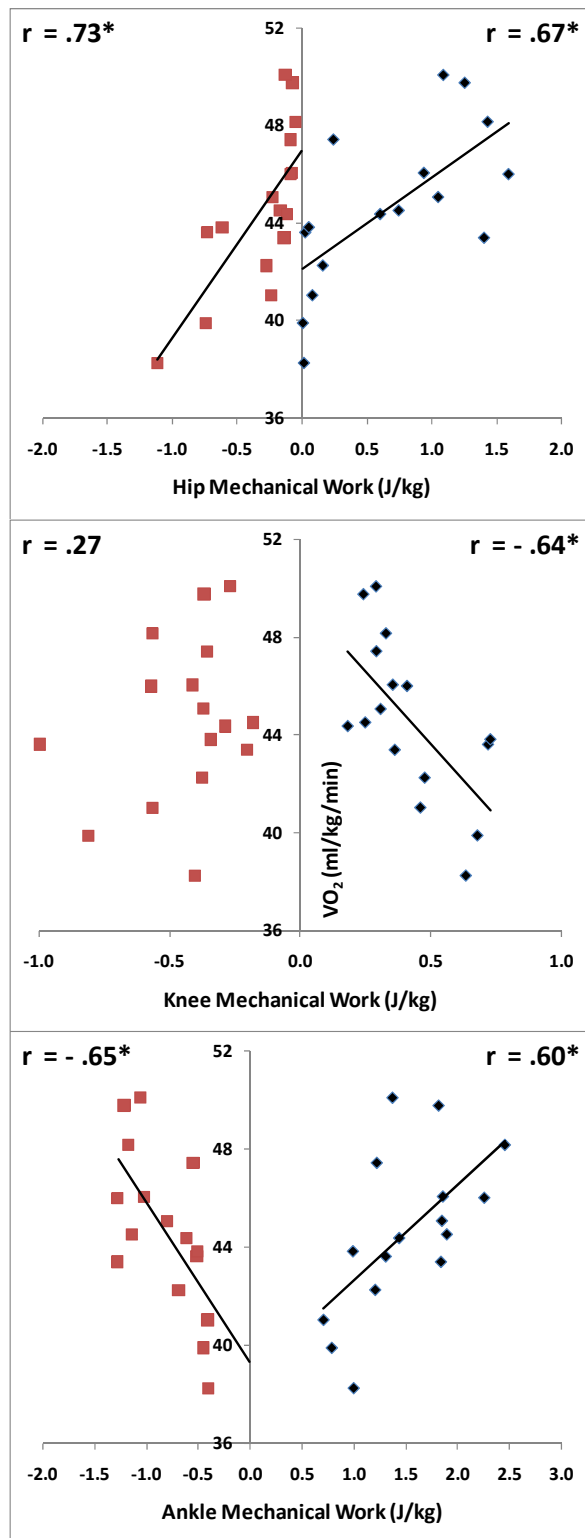


Figure 1. Scatterplots of metabolic cost ($\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) and positive/negative mechanical work at the hip (top), knee (middle), and ankle (bottom). * $p < .05$

HIP	0.67 ± 0.59	-0.30 ± 0.32
KNEE	0.42 ± 0.18	-0.44 ± 0.22
ANKLE	1.50 ± 0.52	-0.82 ± 0.33

Table 1. Mean (\pm SD) Positive and Negative Mechanical Work ($\text{J}\cdot\text{kg}^{-1}$).

DISCUSSION

As shown in Table 1, the hip and ankle displayed more positive work than negative work, similar to the findings of DeVita et al. (2007). During stance, the total positive work ($2.59 \text{ J}\cdot\text{kg}^{-1}$) produced by all joints of the lower extremity was greater than the total negative work ($-1.56 \text{ J}\cdot\text{kg}^{-1}$). The work at the knee, however, did not agree with DeVita et al. and showed no difference between positive and negative work. Positive work at the hip and ankle are both nearly double the corresponding negative work (see Table 1) and both share positive correlations with RE.

Minimizing energy generation at the hip and ankle, while maximizing energy generation at the knee appear to be important considerations for economical running. The independence of the mechanical work terms will need further consideration in order to make more precise recommendations. In addition, the action of biarticular muscles, which have a prominent role during stance phase (Kram, 2000), may be involved in energy transfer. This mechanism was not addressed by the analytical approach used in the present study.

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