Quantifying the Net Cost of Transport Curve During Human Walking: How Much Time Is Required?

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INTRODUCTION

- The U-shaped net cost of transport (COT) curve shows us that humans naturally select biomechanical conditions that help them minimize energy utilization during walking [1]. One of these biomechanical selections is speed as evidenced by all humans having an optimal walking speed at which they minimize the energy required to move a certain distance.
- While the net COT curve provides unique insight into the determinants that underlie energy minimization, the process of quantifying such a curve is extremely time-consuming because this requires that each subject walk across a range of slow to fast walking speeds and that they reach a steady-rate of metabolism at each particular speed. This process is further complicated by the fact that there lacks an objective criterion that defines the period when a subject has reached a steady rate of metabolism.
- As a result, the generally accepted practice in many walking studies is to use the last 3 minutes of a 6-10-minute walking trial, assuming that a steady-rate metabolism has been achieved [2-3]. This results in a time-consuming protocol, and therefore is not often conducted in walking studies.
- **We propose a slope method for determining the start of steady-rate metabolism.**
- **With the current lengthy protocol in mind, we also sought to determine whether an earlier steady-rate interval could be found and would provide a net cost of transport curve that is not statistically different from that produced by the last 3-minute interval that we consider the current best practice.**

METHODS

- Twenty-one subjects completed a randomized series of 7-minute walking trials across speeds ranging from 0.50-2.00 m/s [4]. We calculated the net metabolic power over the course of each trial for each subject using the average V̇O2 and V̇CO2 values (ParvoMedics) and the Brockway equation [5].
- We divided each 7-minute trial into overlapping 3-minute, 2-minute, and 1-minute intervals, and calculated the slope of net metabolic power over time for each interval per subject.
- We compiled these slopes across all speeds for each subject and averaged them.
- Using Tukey's multiple comparison test, we determined when the average slope value was not statistically different from that of the last 3-minute interval from 4.00-7.00 minutes.
- We calculated net cost of transport by dividing the average value of net metabolic power from each trial shown in Fig. 3. (a) by the speed.

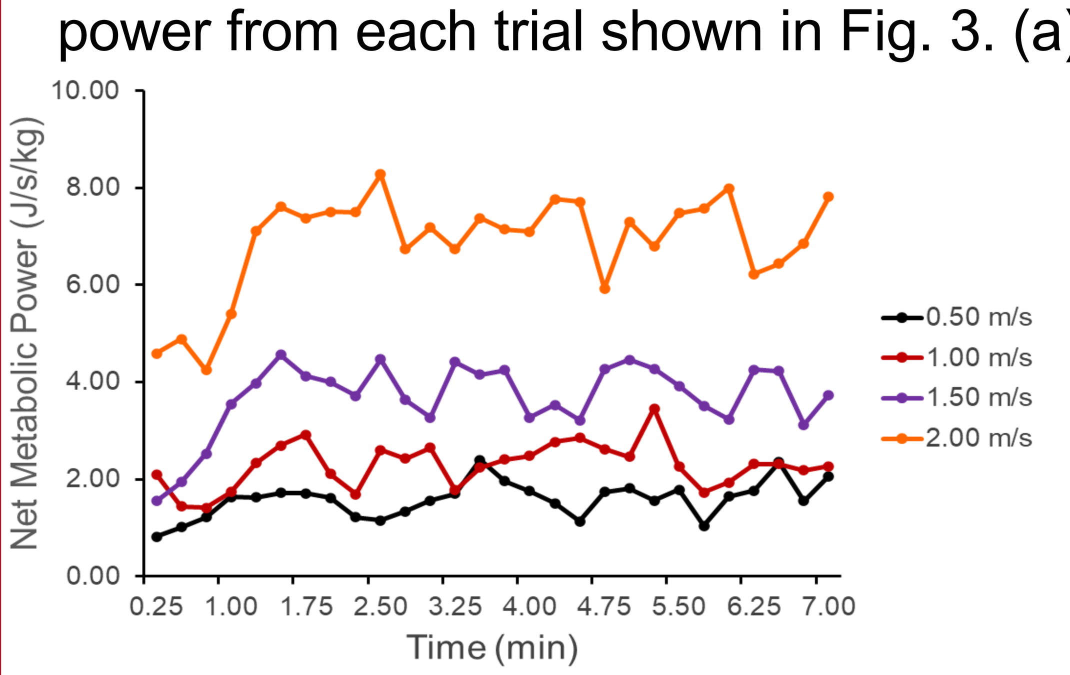

Figure 1. Average time-series course for net metabolic power for a representative subject. Note the sharp rise at the start of the trial that continues until the subject reaches a steady rate of metabolism while walking at moderate to fast speeds. Also note that a greater net metabolic power is required to achieve a faster speed, but nonetheless, a steady rate of metabolism is achieved after two minutes.

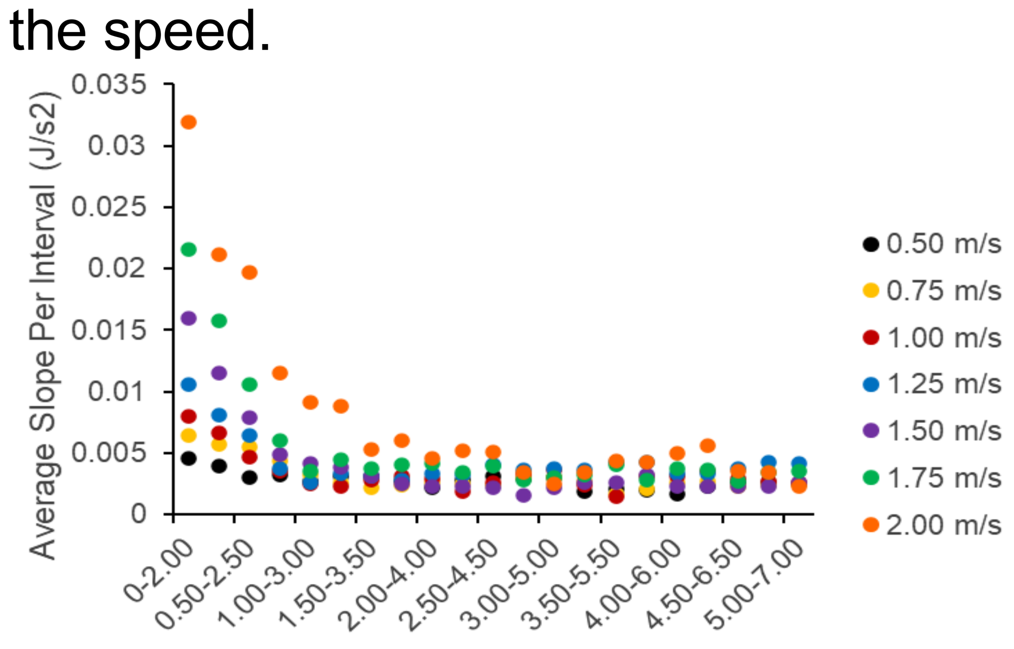

Figure 2. For simplicity, the graph shows for all subjects, the absolute value of the average slopes for only the overlapping 2-minute intervals. Note the downward trend of the average slopes until after two minutes where the average slope value remains fairly constant indicating the attainment of a steady rate of metabolism.

RESULTS AND ANALYSIS

- Statistical comparisons between intervals indicate that a steady rate of metabolism was reached by 2.50 minutes for all subjects at all speeds.
- Using paired t-tests, we found no significant differences between the net COT curve created from the first 2-minutes of steady-rate (2.50-4.50 min) and the widely used method of using the last 3-minute interval of the trial (4.00-7.00 min) (all *p's* >0.05) .

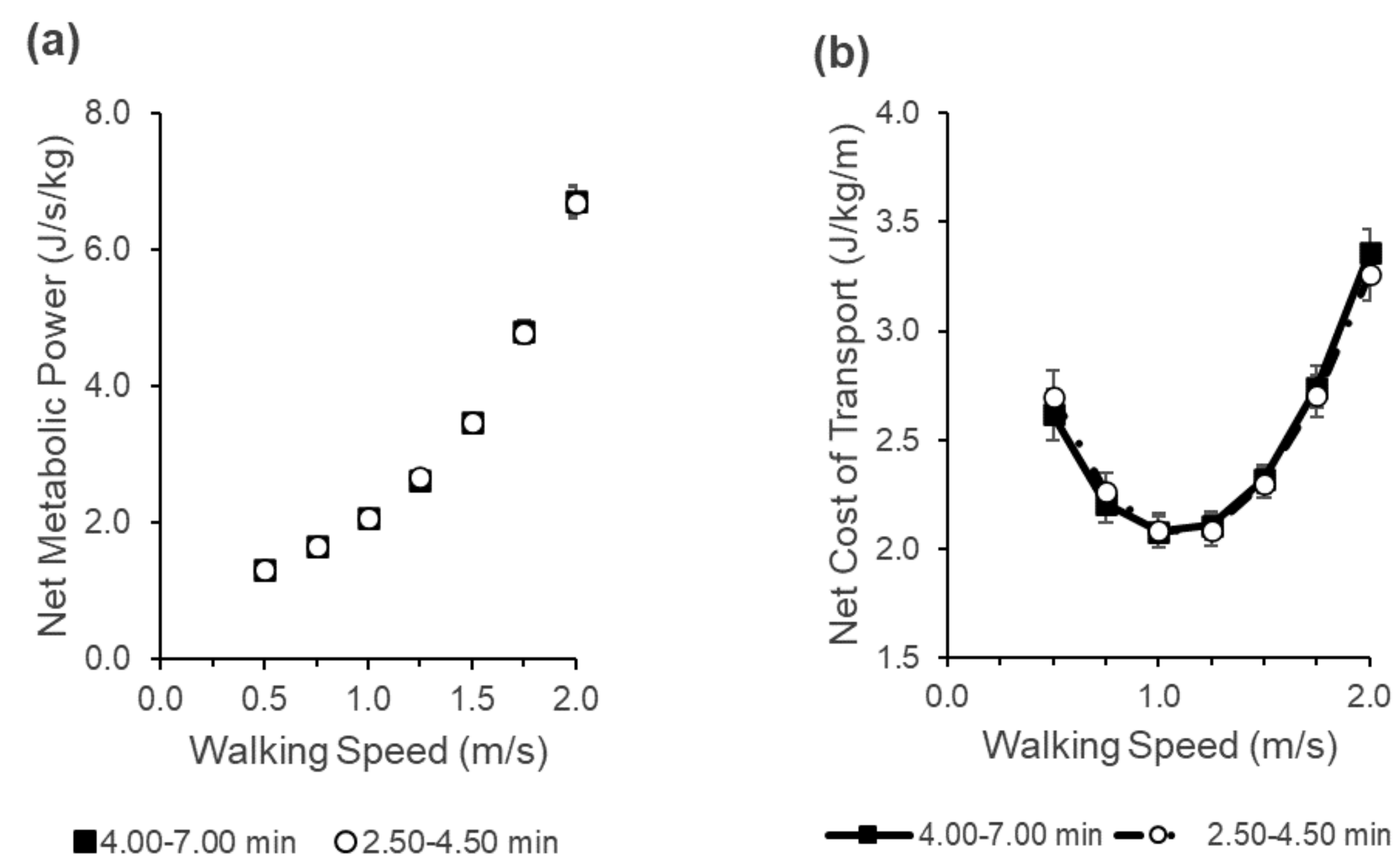

Figure 3. (a) The graph shows how average net metabolic power for all of the subjects increases with speed for the 4.00-7.00 minute and 2.50-4.50 minute intervals of the 7 minute trial. **(b)** The graph shows the net cost of transport (COT) curves for the 4.00-7.00 minute and 2.50-4.50 minute intervals of the 7 minute trial. The net COT curves overlap and are statistically similar, with a minimum value at 1.00 m/s. Furthermore, the graph shows that when humans walk below or above their optimal speed, the net COT increases, indicating that more energy is required to move one kilogram of body mass a unit distance.

KEY FINDING

Our analysis demonstrates that across all walking speeds, a minimum of 5 minutes is needed to generate a net COT curve for human walking. This would drastically reduce the overall experimental time by 7-35 minutes per subject.

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