Real-time Selection of Preferred Step Frequency in Human Walking

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Summary
We investigated the underlying principle of the ability of humans to spontaneously select a locomotion pattern that minimizes energy expenditure. We constrained subjects to a novel relationship between frequency and speed. Subjects did not find the minimum possible cost of transport on this novel relationship. Instead, they were rapidly attracted towards their preferred relationship. Rather than using a real-time cost of transport minimization strategy, this suggests that people use an internal representation of their preferred relationship when selecting their walking pattern.

Introduction
One of the most general principles underlying the control of locomotion is that we tend to select movement patterns that minimize energetic cost. For example, when humans are instructed to walk a given speed they choose the step frequency that minimizes energetic cost. This has been known since the pioneering work of H.J. Ralston[1], yet the mechanisms by which metabolic cost is integrated into the neural control of locomotion are not yet understood. For the real-time selection of movement patterns humans could rely on a real-time optimization of cost of transport (COT; energy expenditure per unit distance), or on an internal representation of the relationship between cost of transport and walking mechanics obtained over longer timescales. The goal of this study was to distinguish between these two hypotheses.

Methods
This study consisted of three experiments. The goal of the first experiment was to determine each subjects preferred relationship between speed and step frequency. In the second experiment subjects were subjected to different enforced relationships between step frequency and speed (Figure 1) by using frequency-dependent speed control. In the third experiment we determined COT along one of the enforced relationships.

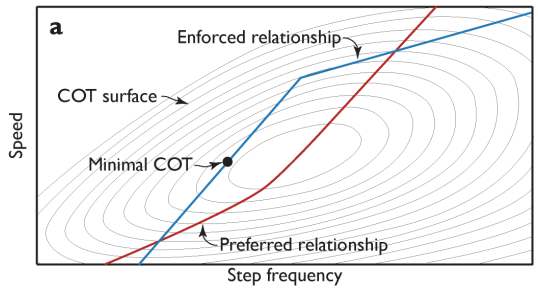

Figure 1: Preferred relationship and enforced relationship in step frequency-speed plane. COT is presented as contour lines, with the minimum in the center.

Results and Discussion
Subjects did not find the minimal COT on the enforced relationship (Figure 2). Instead, they were rapidly attracted towards their preferred relationship (Figure 3). As a result, the behaviour of subjects was strongly depended on the enforced relationship and the combination of frequency and speed just before the frequency-dependent speed control was turned on. We concluded that it is unlikely that humans use a real-time COT minimization strategy for the control of locomotion, but instead use an internal representation between walking mechanics and COT.

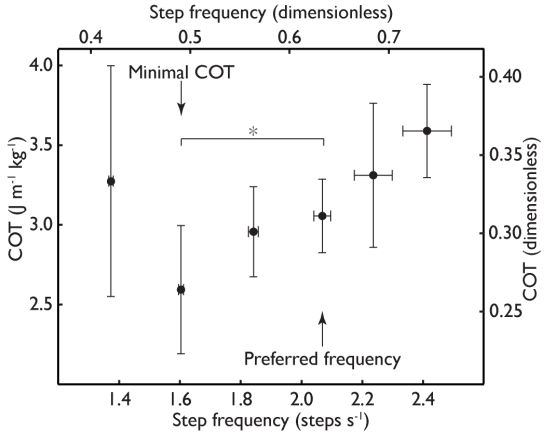

Figure 2: The frequency subjects preferred to walk on resulted in a COT 15% higher than minimum.

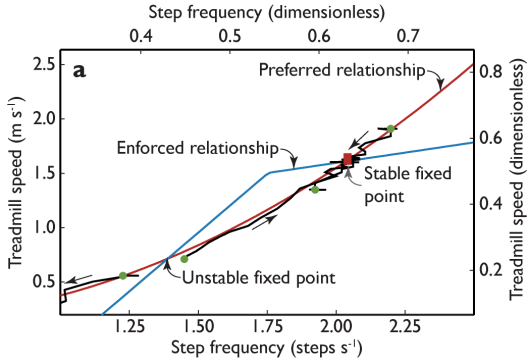

Figure 3: For this enforced relationship subjects either settled into the higher intersection of the two relationships, or stopped walking.

References
1. Ralston, H.J. *Int Z Angew Physiol.* **17**, 277-83, 1958.