Walking as an exercise modality for stimulating energy metabolism and lower extremity muscle functions

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Summary

We examined the effects of gait alterations (i.e., variations in cadence and stride length) on energy metabolism and muscle activity. Twelve young adults walked on a treadmill under seven gait conditions with controlled walking speed and cadence. Muscle activity, joint angles, and energy metabolism were analyzed. The results demonstrated that cadence changes primarily affected biarticular muscles, while stride length changes had a greater impact on monoarticular muscles. Enhancing walking speed by focusing on either cadence or stride length, rather than increasing both simultaneously, was found to be more effective in enhancing energy metabolism and muscle activation.

Introduction

Walking is a fundamental exercise promoting health, independence, and longevity [1]. Previous studies have shown that gait patterns (combination of stride length and cadence) follow age-related changes [2] and that energy cost of transport (COT) follows a U-shaped curve with increasing speed [3]. However, it remains unclear which gait pattern has the most significant impact on energy metabolism and muscle activation. This study aimed to analyze how different walking conditions affect lower limb metabolic cost and muscle activity, toward optimizing walking as the tool for health promotion.

Methods

Twelve healthy young adults (6 males, 6 females, age: 23.2 ± 3.8 years) participated. Walking conditions were based on combinations of preferred walking speed (determined with a self-paced waling on a flat floor surface) and cadence set as follows: (1) 60% speed × 60% cadence, (2) 60% speed × 80% cadence, (3) 100% speed × 80% cadence, (4) 100% speed × 100% cadence, (5) 100% speed × 120% cadence, (6) 140% speed × 120% cadence, and (7) 140% speed × 140% cadence. Treadmill walking was performed for 5 minutes per condition with a metronome to control cadence.

We measured the following parameters: 1) muscle activity using surface EMG (Trigno Wireless System) from six lower limb muscles (rectus femoris [RF], vastus lateralis [VL], biceps femoris long head [BF], tibialis anterior [TA], gastrocnemius medialis [MG], and soleus [Sol]), 2) joint angles at hip, knee, and ankle using OpenCap (Stanford University, USA) markerless motion capture, and 3) energy metabolism, including cost of transport (COT), respiratory exchange ratio (RER), and energy expenditure (EE), using a expired gas analyzer (MetaLyzer3B, Japan). We calculated COT and RER with the following equations:

$$COT = VO_2 / Weight / speed \times 60$$

$$EE = 3.9 \times VO_2 + 1.1 \times VCO_2$$

Results and Discussion

The cadence-weighted condition at 140% speed showed the highest RMS, COT, and EE values, suggesting greater metabolic and muscular demands. Preferred and cadence & stride length controlled 100% speed conditions showed no significant differences. However, stride length-weighted condition increased VL, TA, and Sol activation ($p<0.05$), while cadence-weighted condition elevated RF and BF activation ($p<0.05$). Low-speed conditions highlighted reductions in RF and BF activity when cadence decreased, while stride length reductions mainly impacted VL and Sol (Figure 1). Transitioning from 60% to 100% speed revealed that either cadence- or stride length-weighted increases in walking speed was more effective in stimulating energy metabolism and muscle activity compared to an even increase of both.

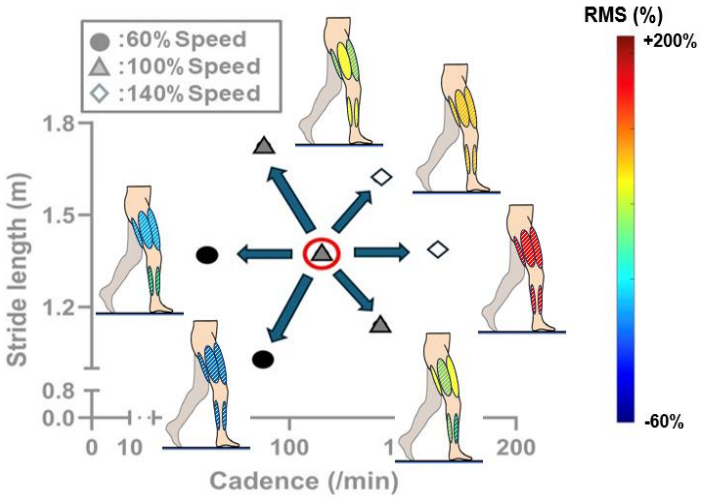

Figure 1: Comparison of Muscle Activity in Preferred and Other Walking Speed Conditions

Conclusions

This study demonstrated that increasing cadence led to greater engagement of biarticular muscles (RF, BF, MG), whereas increasing stride length affected monoarticular muscles (VL, TA, Sol). Enhancing walking speed by focusing on either cadence or stride length, rather than increasing both simultaneously, was more effective in increasing energy expenditure and muscle activation.

References

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