Original Article

Microvascular Control Mechanism of the Plantar Foot in Response to Different Walking Speeds and Durations: Implication for the Prevention of Foot Ulcers

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Abstract

Physical activity has been recommended by the American Diabetes Association (ADA) as a preventive intervention of diabetes complications. However, there is no study investigating how microvascular control mechanism respond to different walking intensities in people with and without diabetes. The purpose of this study was to assess microvascular control mechanism of the plantar foot in response to various walking speeds and durations in 12 healthy people using spectral analysis of skin blood flow (SBF) oscillations. A 3×2 factorial design, including 3 speeds (3, 6, and 9 km/h) and 2 durations (10 and 20 minutes), was used in this study. Plantar SBF was measured using laser Doppler flowmetry over the first metatarsal head. Borg Rating of Perceived Exertion (RPE) scale and heart rate maximum were used to assess the walking intensity. Wavelet analysis was used to quantify regulations of metabolic (0.0095-0.02 Hz), neurogenic (0.02-0.05 Hz), myogenic (0.05-0.15 Hz), respiratory (0.15-0.4 Hz), and cardiac (0.4-2 Hz) controls. For 10-minute walking, walking at 9 km/h significantly increased the ratio of wavelet amplitudes of metabolic, neurogenic, myogenic, respiratory, and cardiac mechanisms compared with 3 km/h ($P < .05$). For 20-minute walking, walking at 6 km/h significantly increased the ratio of wavelet amplitudes of metabolic, myogenic, respiratory, and cardiac compared with 3 km/h ($P < .05$). RPE showed a significant interaction between the speed and duration factors ($P < .01$). This is the first study demonstrating that different walking speeds and durations caused different plantar microvascular regulations.

Keywords

diabetic foot ulcer prevention, laser Doppler, skin blood flow, walking duration, walking speed, wavelet analysis

Introduction

Diabetes mellitus (DM) is a common metabolic disease that causes various complications. Diabetic foot ulcers (DFUs), one of the most severe complications of DM, is a major cause for hospitalization and lower extremity amputation.[1] DFUs cost approximately $9 to $13 billion per year in the United States health care system.[2] An estimated 19% to 34% of the people with DM will develop DFUs in their lifetime.[1] As the medical expenditure and incidence of DFUs remains high, the prevention of DFUs is highlighted in the diabetes care.[3,4]

Many factors have been demonstrated to contribute to the development of DFUs, including peripheral neuropathy, increased plantar pressure, abnormal plantar soft tissue mechanical property, and microvascular dysfunction.[1,5-7] Microvascular dysfunction in people with DM is due to capillary basement membrane thickening, shrinking capillary size, pericyte degeneration, and endothelial dysfunction.[8] The interactions of all causative factors result in a higher plantar pressure acting on a stiffer plantar foot with impaired vasodilatory function to overcome plantar ischemia caused by weight-bearing activities (eg, standing and

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