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ORIGINAL ARTICLE

Reduction in Energy Expenditure During Walking Using an Automated Stride Assistance Device in Healthy Young Adults

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Abstract

Objective: To investigate the effects of an automated stride assistance device that assists hip joint flexion and extension movement in energy expenditure during walking in healthy young adults using an expired gas method.

Design: Prospective, single-group design to compare the differences of energy expenditure between 2 assistive conditions.

Setting: Laboratory.

Participants: Healthy volunteers (N = 10) aged 21 to 32 years.

Interventions: Not applicable.

Main Outcome Measures: Oxygen consumption per unit time ($\dot{V}O_2$) cost ($ml \cdot kg^{-1} \cdot m^{-1}$), and heart rate (beats/min) were measured in 2 assistive conditions (with 3-Nm hip motion assistance and without assistance) and at 2 walking speeds (comfortable walking speed [CWS] and maximum walking speed [MWS]).

Results: There were no significant differences in walking speed between the with- and without-assistance conditions at either the CWS or MWS. The $\dot{V}O_2$ cost and heart rate were significantly reduced in the with-assistance condition compared with the without-assistance condition, at both the CWS and MWS. The reduction in the $\dot{V}O_2$ cost during the with-assistance condition, relative to the without-assistance condition, was 7.06% at the CWS and 10.52% at the MWS.

Conclusions: The automated stride assistance device is useful for reducing energy expenditure during walking in healthy adults. Further studies are warranted to investigate if this device provides substantial help to individuals with impaired mobility as a result of strength deficits.

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Because gait is a fundamental component of performing activities of daily living, regaining the ability to walk is a major rehabilitation goal in patients with neurologic disorders and orthopedic diseases. Recently, several robot-assisted gait devices have been developed to facilitate gait rehabilitation and improve walking in patients with gait disorders. The effects of these devices have been previously reported.[1-5] For instance, a robotic electromechanical gait trainer with foot-driven plates[3] and a robot-driven gait orthosis (eg, exoskeleton robotic device)[4] were reported to significantly improve activities of daily living and walking ability in patients with stroke and incomplete spinal cord injury (SCI). However, these conventional robot-assisted gait devices include large equipment (eg, body weight-supported devices, trunk suspension systems, treadmills).[1-5]

In contrast with these conventional robot-assisted gait devices, the Stride Management Assist Device,[6-8,a] which was developed to enhance effective walking and increase the daily life space in older adults and patients with gait disorders, is lightweight (2.6kg) and can be used outdoors. This device is an automated stride assistance system that assists hip joint flexion and extension movement during walking. The Stride Management Assist Device has a lumbar support, 2 thigh supports, 2 thigh frames, and 2 electrical actuators (fig 1). The torque

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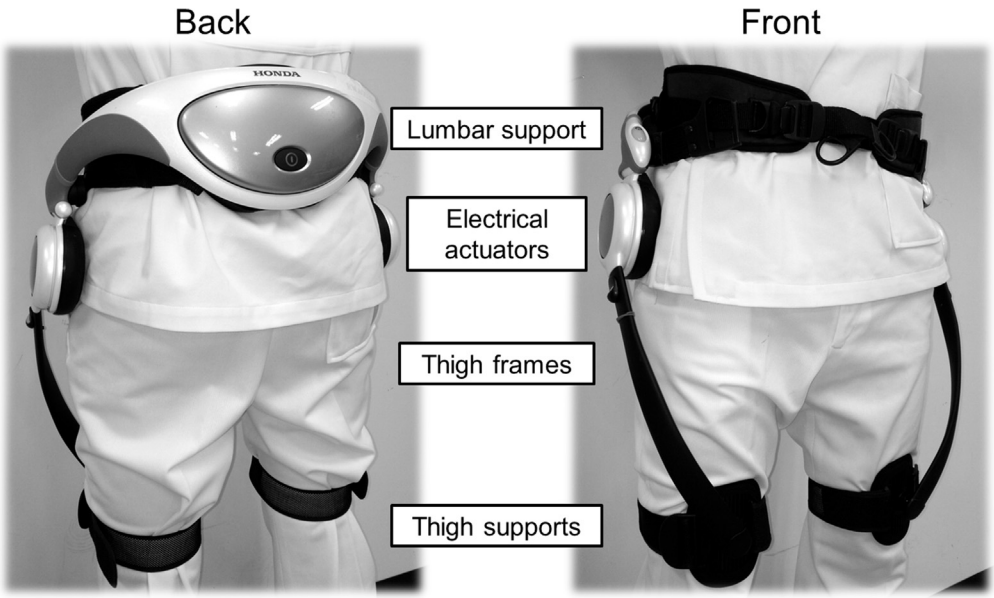

Fig 1 Stride Management Assist Device, which is an automated stride assistance system that has a lumbar support, 2 thigh supports, 2 thigh frames, and 2 electrical actuators. The electrical actuators are equipped with angular and current sensors to monitor the range of motion (degrees) for hip joint extension and flexion and torque (Nm) generated by the Stride Management Assist Device.

assistance generated by the Stride Management Assist Device is transmitted to the thighs through the thigh frames.

Shimada et al[8] demonstrated the effects of a 3-month walking exercise intervention using the Stride Management Assist Device in older adults. The effects of the Stride Management Assist Device have been described in relation with lower-limb muscle glucose metabolism.[6-8] The Stride Management Assist Device significantly improved walking speed and reduced the glucose metabolism of the lower-limb muscles (eg, gluteus medius, rectus femoris) in older adults.[8] However, in a previous study in healthy young adults who increased walk ratios (step length/cadence) with the Stride Management Assist Device, ankle plantarflexor muscle glucose metabolism was reported to increase after walking using the device.[6] Therefore, the Stride Management Assist Device torque assistance may reduce the load on the hip joint, and an increased walking speed using the Stride Management Assist Device is expected to increase the load on the shank muscles during walking. However, because previous studies investigated only the local lower-limb muscles,[6-8] the effects of the Stride Management Assist Device on whole-body energy expenditure during walking, which is an accurate indicator of walking efficiency,[9] are still unclear.

Energy expenditure during gait is increased in patients with gait disorders.[9-11] These patients are reported to have high energy expenditure, such as oxygen consumption per unit time ($\dot{V}O_2$) and heart rate, during gait.[9-11] For example, $\dot{V}O_2$ cost, which is defined as the $\dot{V}O_2$ used per unit of the distance covered, was reported to be .15mL/kg/m in healthy adults, but it was .27ml$\cdot$kg$^{-1}\cdot$m^{-1} in patients after stroke and between .26 and 76mL/kg/m in patients with SCI,[9] inducing low walking endurance in these patients.[9,11] It is important for these patients to reduce energy expenditure during walking to regain the ability to walk and perform activities of daily living. Therefore, investigating the energy expenditure effects of the Stride Management Assist Device provides significant information for a better understanding of using the Stride Management Assist Device for gait rehabilitation in patients with gait disorders. The purpose of the present study was to investigate the effects of the Stride Management Assist Device on energy expenditure during walking in healthy young adults using an expired gas method.

List of abbreviations:

CWS	**comfortable walking speed**
MWS	**maximum walking speed**
SCI	**spinal cord injury**
$\dot{V}o_2$	**oxygen consumption per unit time**

Methods

Participants

We recruited volunteers who met our inclusion criteria. Healthy young adults (N=10; 5 men, 5 women; mean age, 24.4±3.5y; height, 166.2±9.2cm; mass, 57.3±10.1kg; body mass index, 20.6±1.7kg/m^2) participated in the present study. Exclusion criteria included presence and history of any diseases (eg, lower-limb orthopedic diseases, neurologic disorders, heart failure, cardiovascular disease, pulmonary disease) that affect walking capacity, endurance, efficiency, and energy expenditure (eg, $\dot{V}O_2$ cost, heart rate during walking). All participants provided informed consent before measurements. All procedures were approved by the ethics committee of Kyoto University Graduate School and Faculty of Medicine and were consistent with the Declaration of Helsinki.

Stride Management Assist Device

The Stride Management Assist Device is an automated stride assistance system. The Stride Management Assist Device's electrical actuators are equipped with angular and current sensors to monitor the range of motion (degrees) for the hip joints and torque (Nm) generated by the device (fig 2). The torque assistance generated by the electrical actuators placed near the hip joints is