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Original Research

Use of an Ankle-Foot Orthosis Improves Aerobic Capacity in Subacute Hemiparetic Stroke Patients

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Abstract

Objective: To investigate aerobic capacity with and without an ankle-foot orthosis (AFO) in subacute hemiparetic stroke patients.
Design: Prospective crossover intervention study.
Setting: Rehabilitation clinic in secondary care.
Patients: Patients diagnosed with first-ever cerebral stroke involving the cortical or subcortical area resulting in hemiparesis ($n = 15$, 8 men and 7 women; average age, 62.1 years).
Methods: All subjects participated in 2 continuous, symptom-limited, low-velocity graded treadmill exercise stress tests under 2 different conditions, namely, with and without an AFO. The rest interval between tests was at least 48 hours. The order of exercise stress tests was randomized.
Main Outcome Measurements: To assess cardiorespiratory responses, oxygen consumption, heart rate, systolic blood pressure, diastolic blood pressure, rate-pressure product, and respiratory exchange ratio were measured continuously throughout the test, and peak values were obtained. The rating of perceived exertion was recorded immediately after each test. The percentage of the age-predicted maximal heart rate and total exercise duration were also measured. Gait function was assessed by the Six-Minute Walk Test.
Results: Using an AFO significantly increased peak oxygen consumption and Six-Minute Walk Test results. Peak values of each of heart rate, systolic blood pressure, diastolic blood pressure, rate-pressure product, and respiratory exchange ratio, rating of perceived exertion, percentage of age-predicted maximal heart rate, and total exercise duration were similar regardless of AFO use.
Conclusions: Use of an AFO may improve aerobic capacity in subacute hemiparetic stroke patients, and may improve energy efficiency and gait endurance.

Introduction

A major cause of disability is stroke, a common symptom of which is impaired gait function [1]. Although one study [2] reported that 85% of patients are able to walk independently with or without an aid at 6 months after their stroke, only 25% of these patients regain a normal gait pattern. After stroke, residual hemiparesis mostly leads to an asymmetrical gait pattern; that is, stroke patients show a typical gait characterized by muscle weakness, impaired balance, and poor intermuscular interjoint/intersegmental coordination [3,4]. Walking with a hemiparetic gait requires more energy than walking with a normal gait [5], and immobility-related deconditioning increases cardiovascular risk for stroke patients in a vicious cycle [6,7].

A recent study [8] reported that hemiparetic gait patterns may increase the energy cost of walking, thereby limiting activities of daily living (ADL) and impairing aerobic capacity in chronic stroke patients.

The standard method for estimating aerobic capacity is to measure oxygen consumption (Vo_2) [9]. One study [10] of 25 adult hemiparetic patients with subacute stroke showed that Vo_2 peak was as low as 60% to 70% of the age- and gender-related normative values for sedentary individuals. Another study reported that gait deviation caused by muscle weakness could decrease one's ability to reach maximal aerobic capacity as assessed using standard exercise stress tests [11].

Ankle-foot orthoses (AFOs) are usually prescribed for stroke patients with a hemiparetic gait. A recent study reported that AFOs prevent the paretic foot from

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dragging when patients walk, and that AFO use may decrease the energy cost of walking and increase speed in people with chronic stroke [8]. However, this study recruited only chronic stroke patients and measured limited values, such as energy consumption, by a treadmill test on even level ground at a constant walking speed. For these reasons, the results are not readily generalizable to environments encountered in real life, such as variable gradients, or to other subgroups of stroke patients.

A major rehabilitation goal for stroke patients is to increase their functional exercise capacity and walking endurance in the community. We hypothesized that using an AFO on the hemiparetic lower limb could improve aerobic capacity and walking endurance in subacute stroke patients.

Therefore, this study aimed to measure cardiorespiratory responses of subacute stroke patients elicited during an incremental exercise stress test during which the gradient is increased gradually. Patients carried out the stress test twice, once with and once without an AFO. The results were compared to demonstrate whether AFOs confer any benefit in terms of cardiovascular fitness and gait endurance during walking in the sorts of real-life environments encountered by these patients.

Methods

Participants

In total, 15 patients (8 men and 7 women; average age, 62.1 years; range, 45-76 years) with subacute (ie, within 3 months) stroke participated in this study. The patients were recruited after attendance at the Department of Physical Medicine and Rehabilitation in our hospital between September 2012 and June 2013 for first-ever cerebral stroke involving the cortical or subcortical area. Their diagnosis was confirmed clinically by computed tomography or magnetic resonance imaging. Patient evaluation included a medical history, physical and neurological examinations, a resting 12-lead electrocardiogram (ECG; CH 2000 Cardiac Diagnostic System, Cambridge Heart Inc, Tewksbury, MA), and calculation of body mass index (BMI). Our inclusion criteria included the ability to walk at least 3 minutes with or without an aid, but without standby assistance, and an ankle dorsiflexor muscle weakness grade of "less than fair" on the hemiparetic side as assessed manually by muscle test. Exclusion criteria were as follows: advanced congestive heart failure, peripheral arterial disease with claudication, unstable angina, uncontrolled hypertension (>190/110 mm Hg), severe cognitive impairment with a Korean version of the Mini-Mental Status Examination (K-MMSE) score of <10 or aphasia (clinically evaluated by a physiatrist), subacute systemic illness or infection, significant orthopedic or pain conditions that limited participation in exercise testing, and other contraindications to exercise testing as identified by the American College of Sports Medicine (ACSM) [12].

Baseline demographic and stroke-related data are presented in Table 1. The average age of the patients was 62.1 ± 9.6 years, and the average post-stroke duration was 34.4 ± 20.8 days.

All participants provided written informed consent form, and our local Ethics Committee approved the study protocol.

Procedures

All subjects underwent 2 continuous, symptom-limited, low-velocity, graded treadmill exercise stress tests with and without an AFO (Figure 1). We used conventional plastic AFOs that had a posterior leaf-type design and were fabricated by a lamination or vacuum-forming technique over a positive plaster model of the limb. The exercise tests followed the protocol reported by Macko et al [13] and were conducted on a calibrated motorized treadmill (T-2100; GE Healthcare Inc, Chalfont St. Giles, UK) in the presence of one physiatrist and one physical therapist. An initial round of treadmill walking at 0% incline was used to assess gait safety and to select the target walking velocity that was comfortable for subsequent maximal-effort graded treadmill testing. The 0-incline treadmill test was started at 0.5 miles per hour (mph) (0.8 km/h) and slowly advanced in increments of 0.1 mph (0.16 km/h) in line with the patient's subjective tolerance and observer-rated gait stability. Patients capable of performing treadmill walking at ≥0.5 mph for 3 minutes or more

Table 1
Demographic and disease-related characteristics of the participants (N = 15)

Variable	Values
Age at stroke onset, y	62.1 ± 9.6
Gender, males/females	8 (53.3)/7 (46.7)
Post-stroke duration, days	34.4 ± 20.8
Height, cm	163.0 ± 9.7
Weight, kg	61.2 ± 10.1
Body mass index, kg/m^2	22.9 ± 2.5
Stroke type	
Ischemic	10 (66.7)
Hemorrhagic	5 (33.3)
Stroke area	
Cortical	1 (6.7)
Subcortical	14 (93.3)
Lesion side	
Left, n	7 (46.7)
Right, n	8 (53.3)
Comorbidities	
Cardiovascular disease	1 (6.7)
Diabetes mellitus	5 (33.3)
Hypertension	8 (53.3)

Values represent mean ± standard deviation or number (%) of cases.