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ORIGINAL RESEARCH

Energy expenditure and cost of walking and stair climbing in individuals with chronic stroke

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Abstract
Background: Subjects with stroke show higher energy cost (EC) during walking, when compared to healthy individuals, but the mechanisms are not fully understood. Additionally, the behavior of physiological variables during other activities has not been investigated.
Objectives: To investigate energy expenditure (EE) and EC during the six-minute walking test (6MWT) and stair climb test (SCT) in chronic stroke subjects compared to healthy controls.
Methods: Cross-sectional study in which stroke subjects ($n = 18$) (community-walking speed ≥ 0.8 m/s) or limited-community <0.8 m/s walkers and matched healthy controls ($n = 18$) had their EE and EC assessed during the 6MWT and SCT with a portable monitoring system.
Results: Significant differences in EE were observed for both the 6MWT (MD 7.29; 95%CI 4.08–10.50) and SCT (MD 8.53; 95%CI 5.07–12.00) between the stroke and control groups, but not between the stroke subgroups. Significant between-group differences in EC were found for both the 6MWT and SCT. For the 6MWT, differences were significant between the limited-community and the community walkers (MD 0.19; 95%CI 0.05–0.33) and controls (MD 0.17; 95%CI 0.04–0.29). No significant differences were found between the community walkers and controls (MD 0.02; 95%CI −0.09 to 0.13). For the SCT, the limited-community walkers showed highest EC, followed by the community walkers, and controls.
Conclusions: Both stroke subgroups demonstrated lower EE compared to healthy controls. During the 6MWT, the limited-community walkers demonstrated higher EC compared to the community walkers and controls. During the SCT, the limited-community walkers demonstrated higher EC, followed by the community walkers, and controls.
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Introduction

Physiological energy measurements are reliable methods to assess quantitatively the changes imposed by gait disabilities.[1] After a stroke, individuals are left with several impairments and disabilities, which interfere with their movement efficiency. Although the mechanisms are not fully understood, the higher energy cost (EC) of walking after stroke has been linked to reduced walking performance and restrictions in community participation.[2]

The Compendium of Physical Activities[3] provides normative data for the estimation of metabolic cost of hundreds of specific daily activities for healthy individuals. Meanwhile, it was observed that, even for the elderly, the real metabolic costs of daily activities are substantially different from the normative values proposed by the Compendium. In addition, mobility impairments may increase the metabolic cost[4] of everyday activities. In this sense, it is important to know if, after stroke, the severity of impairments and levels of disabilities could affect the efficiency of the movement.

Previous studies[5–7] used treadmills to examine the differences in oxygen consumption between stroke and healthy individuals. The advantage of using treadmills is that walking speeds can be more easily controlled.[8] However, the automaticity provided by the treadmills is not comparable to that of daily activities, which can impose different demands on individuals with stroke. A recent study[9] reported that, compared to healthy controls, stroke individuals demonstrated lower energy expenditure (EE) and EC during the performance of typical motor activities, such as sit-to-walk-to-sit, walking over an obstacle, walking at comfortable speeds, and reaching for an object, while in a standing position.[9]

A recent systematic review[10] that included four studies compared the EE and EC of stroke and healthy individuals during walking. These studies investigated these variables during overground walking, with a mean sample of 30 individuals, including both stroke and healthy controls. In this sense, even for the most basic daily activity, i.e., overground walking, there is still limited information regarding the differences in EE and EC between stroke and healthy individuals. For example, no studies were found that compared the energy variables of stroke individuals with different functional levels (i.e., various walking speeds) to healthy controls. Similarly, no study was found that investigated the behavior and characteristics of energy variables in individuals with stroke during stair management. For instance, stairs are common in many places[11] and the ability to manage stairs has been shown to be the best predictor of free-living physical activity with community-dwelling stroke individuals.[12] However, there is no available data regarding the metabolic demands during stair negotiation in individuals with stroke.

Therefore, the aim of this study was to investigate EE and EC during the performance of the six-minute walking test (6MWT) and stair climb test (SCT) in individuals with chronic stroke, who were classified as community and limited-community walkers, compared to age- and sex-matched healthy controls.

Methods

Design

For this cross-sectional study, the participants were recruited from the general community and outpatient physical therapy clinics of the city of Belo Horizonte, Brazil. This study was conducted from September to December 2014. The outcome measures were collected in random order, during the afternoons, over one day in a university laboratory setting. Prior to the data collection, at least 500 mL of water were provided to the participants to ensure normal hydration. The participants were asked to avoid strenuous activity in the previous 24 h and to keep taking their usual medications. In addition, they were asked to avoid taking any stimulants, such as coffee, black tea, or chocolate, on the day of the test. This study was approved by the Research Ethics Review Board of Universidade Federal de Minas Gerais (UFMG), Belo Horizonte, MG, Brazil (#ETIC 0254.0.203.000.11), and prior to data collection, all participants provided written consent.

Participants

Individuals with chronic stroke were eligible if they were $\geq$20 years of age, had a mean duration of unilateral stroke between one and five years, and were able to walk at least 14 m independently, without walking aids. They were excluded if they had cognitive deficits as determined by the following Brazilian education-adjusted cut-off scores on the Mini-mental state examination: 18/19 for the individuals with illiteracy and 24/25 for those with basic education[13] or any other neurological or orthopedic disorder.

The outcome measures were collected by two well-trained physical therapists, who had clinical and research experience in stroke rehabilitation. Characteristics, such as age, sex, paretic side, time since the onset of the stroke, tonus of the plantar-flexor muscles (modified Ashworth scale), functional independence (Barthel Index), motor recovery (Fugl-Meyer – lower extremity section scores), minute ventilation-carbon dioxide production (VE/VCO_2), and respiratory exchange ratio (RER), were collected. During the 6MWT and SCT, the mean perceived exertion was collected. Based on their walking speed values, the individuals with stroke were stratified into two clinically functional subgroups: community walkers (walking speed $\geq$0.8 m/s) and limited-community walkers (walking speed <0.8 m/s).[14]

Outcomes

Measures of EE, determined by oxygen consumption (VO_2) in $mL\,kg^{-1}\,min^{-1}$ during the 6MWT and SCT, were randomly collected with a portable monitoring system (Metamax 3B – Cortex, Leipzig, Germany), which provides reliable measures in individuals with chronic stroke during walking.[15]

The 6MWT, which has shown acceptable test–retest reliability for individuals with stroke,[16] was performed according to the procedures and recommendations of the American Thoracic Society.[17] For the SCT, the individuals