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ORIGINAL ARTICLE

Comparison of Metabolic Cost and Cardiovascular Response to Stair Ascending and Descending With Walkers and Canes in Older Adults

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Abstract

Objective: To compare oxygen cost ($mL \cdot kg^{-1} \cdot m^{-1}$) and cardiovascular response (beats/m) and oxygen consumption ($mL \cdot kg^{-1} \cdot min^{-1}$) and heart rate (beats/min) to stair ascending and descending with walkers, with canes, and without assistive devices (ADs) in older adults.

Design: Descriptive, repeated measures.

Setting: Indoor stairway.

Participants: Convenience sample of able-bodied volunteers, non-AD users (N=14; mean age, 63.71±11.7y; mean body mass, 72.7±14.1kg; mean height, 165.7±9.2cm).

Interventions: Participants performed 4 randomized trials of stair ascending and descending at their own self-selected speed with 3 ADs: single-point cane, standard walker (SW), and wheeled walker (WW). They also performed unassisted stair ascending and descending. Each trial consisted of a 5-minute steady-state session followed by a 2-minute data collection period. Steady-state expired ventilations were collected in Douglas bags for metabolic analysis.

Main Outcome Measures: Oxygen cost ($mL \cdot kg^{-1} \cdot m^{-1}$), heart rate (HR) response (beats/m), oxygen consumption ($mL \cdot kg^{-1} \cdot min^{-1}$), and HR (beats/min) were compared for each trial of stair ascending and descending using analysis of variance repeated measures ($P<.05$).

Results: Greater oxygen cost (per meter) was found for stair ascending and descending using the single-point cane (121%), SW (217%), and WW (232%) compared with unassisted stair ascending and descending ($P<.05$). Increased HR response (per meter) was found for stair ascending and descending using the single-point cane (116%), SW (126%), and WW (147%) compared with unassisted stair ascending and descending ($P<.05$). However, oxygen consumption (per minute) and HR (per minute) were not significantly increased during stair ascending and descending with the ADs compared with unassisted stair ascending and descending. Participants stair ascended and descended at significantly ($P<.05$) reduced speeds during trials with the ADs.

Conclusions: This research should aid clinicians by providing evidence to base recommendations on regarding AD usage when encountering stairs during home and community ambulation.

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An assistive device (AD) is frequently used to enhance functional ambulation by providing individuals with various physical impairments and disabilities safe and functional means of household and community ambulation. For ADs to be effectively used, the environments in which they are to be used must be accessible.[1] The 2011 American Housing Survey[2] reports that 54 million households have stairs, and roughly about half of U.S. homes have interior stairs. Over 6.8 million community-resident Americans use ADs (eg, canes, crutches, walkers).[1] Use of ADs can increase individuals' levels of activity participation[3] and independence. The health benefits of increased activity participation are numerous and well documented.[4] Clearly, ADs serve an important role in promoting increased activity and participation levels. Considering the high likelihood that AD users will encounter stairs and the need for ADs in order to ascend or descend stairs, what are the metabolic costs and workload demands on the cardiovascular system imposed by AD use on stairs?

Although ADs can enhance overall stability during movement, these devices can also increase cardiorespiratory demands for

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individuals who use them.[5] Numerous studies have reported increases in oxygen cost and/or cardiovascular response to ambulation with various ADs. Further review of these studies[5-14] reveals differences in methodologic approaches for determining oxygen cost and/or cardiovascular response. Some studies[6,8,13] used ambulation at the same speed for comparisons between various ADs. Other studies[9,10,12,14] had participants ambulate with the ADs at self-selected speeds or comfort speeds. Additional methodologic differences were found in the way oxygen cost and cardiovascular response were reported in these studies.[5-14] In some of these studies, oxygen cost and/or cardiovascular response were reported per unit time (minutes); in other studies, oxygen cost and/or cardiovascular response were reported per unit distance. Reporting oxygen cost per unit distance allows for direct scientific efficiency comparisons, similar to the way we compare miles per gallon in motor vehicles. Efficiency comparisons can provide insight into the oxygen cost per unit distance, but it may not be as relevant as clinical physiological per minute responses. Calculating oxygen consumption per unit of time provides clinical insight into the individuals' physiological response during AD usage. Additionally, in some studies both are reported, and emphasis is placed on where statistical significance occurred between the ADs. We believe that the aggregate of these methodologic differences makes interpretation of these results confusing for translational clinical applications.

For the purposes of this study we are differentiating oxygen cost (efficiency) and oxygen rate as described by Waters et al,[15] where oxygen cost or oxygen efficiency ($mL \cdot kg^{-1} \cdot m^{-1}$) is not time dependent and represents the amount of oxygen needed to move over a distance unit. The oxygen rate ($mL \cdot kg^{-1} \cdot min^{-1}$) indicates the intensity of physical effort during an activity and is time dependent. Similarly, we are differentiating cardiovascular response (beats/m) and heart rate (HR) (beats/min). We believe a clear understanding of this distinction is crucial for clinicians when advising patients regarding oxygen cost (per meter) or physiological requirements (per minute) of AD usage. Normative human metabolic cost of ambulation varies according to the speed of ambulation. In an extensive review by Waters and Mulroy,[16] the metabolic cost of ambulation is reported to vary with pathologies. The energy expenditure of normative and pathologic gait also differs with speed.[16] Frequently, when comparisons have been made for ambulation with and without pathologic conditions, speed is held constant for equitable comparison. This makes sense from a comparative scientific approach. However, from a functional perspective, individuals with and without pathologic conditions ambulate at self-selected velocities[16]; therefore, ambulation at controlled speeds may not be the most appropriate condition in which to study the metabolic cost of ambulation with ADs from a functional perspective.

List of abbreviations:

AD	**assistive device**
BP	**blood pressure**
DBP	**diastolic blood pressure**
HR	**heart rate**
MET	**metabolic equivalent**
MMC	**metabolic measurement cart**
RPE	**rating of perceived exertion**
SBP	**systolic blood pressure**
SW	**standard walker**
$\dot{V}O_2$	**oxygen consumption per unit time**
WW	**wheeled walker**

Stair ascending and descending increases oxygen consumption compared with level ambulation.[17-19] According to the Compendium of Physical Activities,[19] normative 4.83km/h walking is 3.3 metabolic equivalents (METs), whereas normative stair ascent (carrying a 0.45 to 6.80kg load) and descent were 5 and 3 METs, respectively.

Individuals do not discontinue AD use when architectural barriers (eg, stairs) are encountered. Individuals frequently encounter stairs and other architectural barriers and must traverse these barriers so they can continue to use the AD after the barriers are crossed. Given the prevalence of AD use and high likelihood of encountering stairs in homes and communities, investigation into the oxygen cost (per meter) and cardiovascular response (per meter) and oxygen consumption (per minute) and HR (per minute) to stair ascending and descending warranted investigation.

Examining the oxygen cost and cardiovascular response per unit distance and physiological rates to the task of stair ascending and descending at self-selected speeds with these selected ADs will allow clinicians to make better clinical decisions regarding AD utilization. We believe assessing the physiological rate (per minute) is more clinically relevant than assessing physiological cost (per distance) regarding clinical decisions on whether an AD is physiologically safe for an individual to use for mobility. To our knowledge, there are no studies that describe oxygen cost (per meter) and cardiovascular response (per meter) and oxygen consumption (per minute) and HR (per minute) to stair ascending and descending with walkers and canes. The purpose of this study was to quantify and compare oxygen cost and cardiovascular response and oxygen consumption and HR to stair ascending and descending with canes, standard walkers (SWs), wheeled walkers (WWs) and unassisted stair ascending and descending in older adults.

Methods

Participants

A convenience sample of 14 able-bodied volunteers from the community was recruited via flyer advertisement for participation in this study. Inclusion criteria were adult volunteers who did not use an AD and who were physically capable of stair ascending and descending with the selected ADs. Prior to testing, each participant completed a medical history questionnaire. Subjects were eliminated from participation if they were currently using an AD or were unable to stair ascend and descend secondary to underlying cardiac, metabolic, or musculoskeletal disorders. Each subject signed an informed consent document in accordance with the university institutional review board before participating in the study.

Familiarization

Before the experimental portion of the study began, a physical therapist conducted an extensive separate familiarization session with each individual subject. The familiarization session consisted of explanation of the testing methods and procedures for this study. Also, during this familiarization session, initial measurements were made and recorded to ensure proper fit of the ADs, with the subject in the standing position. Proper height of the walkers was ensured by an angle of 20° to 30° at the elbow when hands were gripped around the hand pieces. The walker was positioned so that two legs of the walker were even with the