

Increased Energy Cost of Mobility in Chronic Stroke

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Rec date: Oct 04, 2016; Acc date: Oct 19, 2016; Pub date: Oct 22, 2016

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Abstract

The purpose of this study was to compare the energy cost of completing mobility-related activities in chronic stroke to the estimated energy cost found in the compendium of physical activities, a resource that estimates and classifies energy cost of various human physical activities. Men (n=18) and women (n=10) with chronic hemiparetic gait (stroke latency: 4 ± 2 years, age: 60.4 ± 1.6 years, BMI: 31.5 ± 1.1 kg/m²) participated in the study. Portable energy cost monitoring (COSMED K4b2) was performed during five mobility activities of varying intensity to determine metabolic equivalents (METs, or oxygen consumption in multiples of resting level) for each activity. The METs achieved during the five activities were compared to the following compendium MET values for: 1) floor sweeping; 2) stepping in place; 3) over-ground walking; 4) lower speed treadmill walking (1.0 mph at 4% incline); and 5) higher speed treadmill walking (2.0 mph at 4% incline). Measurements were obtained for 10 min at rest and 5 minutes during each of the five activities. The energy cost of rest was only 85% of Compendium METS, while mobility-related activities were ~1.25-1.50 fold greater when measured in stroke vs. Compendium METS for all measures (P's<0.05), except floor sweeping, which was similar between groups. These data indicate that MET levels provided in the compendium are not applicable to chronic stroke survivors as they overestimate energy expenditure at rest and underestimate energy expenditure during physical activity, indicating poor efficiency in movement, thus elevating the oxygen cost of completing general daily activities.

Keywords: Energy expenditure; Mobility; Chronic stroke

Abbreviations

BMI: Body Mass Index; MET: Metabolic Equivalents of Task; RMR: Resting Metabolic Rate

Introduction

Nearly three-quarters of all strokes, which are the leading cause of serious, long-term disability in the USA, occur in people over the age of 65 [1]. Following a stroke, ~80% of individuals develop hemiparesis. Compared to normal controls, hemiparesis increases the energy cost of treadmill walking by 1.5-2.0-fold [2,3], which may result in physical inactivity and fatigue. Indeed, stroke survivors spend ~80% of the day spent performing sedentary activities [4]. Further, up to 70% of stroke survivors report chronic fatigue [5], which is associated with reduced physical functioning in stroke [6,7]. These data suggest value in understanding energy cost of daily activities common among stroke survivors.

One metabolic equivalents of task (MET) is considered the energy cost of a person at rest (1 MET=3.5 ml oxygen consumption/kg body weight/min). MET values for activities of various intensities are available in the compendium of physical activities [8] and are defined as the ratio of working metabolic rate to resting metabolic rate (RMR). The compendium MET levels are derived from published laboratory or

field experiments that measure the oxygen cost of these specific activities. This information can be used to calculate energy expenditure from various activities and can be used to formulate exercise prescriptions to promote physical activity. However, the compendium MET levels are intended for use in able-bodied adults who are 18-65-year-old and may underestimate activities in older individuals and those with disabilities [8]. Hence, the purpose of the present study was to compare compendium MET levels to measured MET levels during lower intensity mobility-related activities, which may ultimately affect assessment of energy expenditure following a stroke.

Methods

Male and female (N=28) chronic (>6 months latency) stroke survivors with residual hemiparetic gait abnormalities were included in the analyses. All subjects were recruited from the Baltimore area. A medical history, physical examination, resting 12-lead electrocardiogram, fasting blood profile, and graded exercise treadmill test were performed to exclude those with unstable medical conditions. Exclusion criteria included congestive heart failure, unstable angina, peripheral vascular disease, orthopedic conditions, and other medical or neuropsychiatric conditions (e.g. significant dementia) limiting participation in aerobic exercise to assure participant safety during testing and training procedures. All participants signed University of Maryland institutional review board approved informed consent forms.

Body composition

Height and body weight were measured using a stadiometer and electric scale to calculate body mass index (weight [kg]/height [m²]). A total body dual-energy X-ray absorptiometry scan (iDXA, LUNAR Radiation Corp., Madison, WI) was performed to determine % body fat.

Indirect calorimetry

We used previously reported procedures [9] to collect breath-by-breath cardiopulmonary data using a portable open circuit spirometry unit (K4b2; COSMED USA) during 10 minutes of rest and five minutes for each of the mobility-related activities. Each participant's mean oxygen consumption (VO₂) for the five activities was determined and converted to METs.

Tests of physical performance and compendium of physical activities comparison

VO₂ peak was measured to assess cardiorespiratory fitness using a graded treadmill test using methods previously described [10]. To increase safety, all participants wore a gait belt.

Participants also performed mobility-related activities with simultaneous indirect calorimetry assessments. The five activities were chosen to capture various lighter (<3.5 METs) intensity mobility-related activities and are described in detail previously [11]. In brief, participants completed each of the following mobility-related activities: 1) stepping in place, 2) floor sweeping, 3) walking around a track, 4) walking on a treadmill at 4% incline at 1 mph (lower intensity), and 5) walking on a treadmill at 4% incline at 2 mph (higher intensity). Similar Compendium of Physical Activities were select for comparison (Figure 1) [8,12]. Since each 3.5% increase in treadmill grade adds ~1 MET to the gross energy cost [13], one MET was added to the treadmill activities since the compendium activities were based on level ground walking.

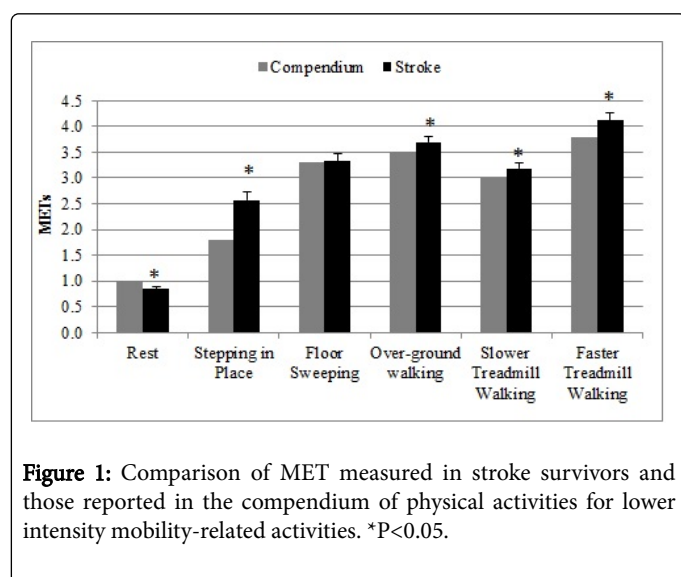


Figure 1: Comparison of MET measured in stroke survivors and those reported in the compendium of physical activities for lower intensity mobility-related activities. *P<0.05.

Statistical Analyses

We utilized one-sample t-tests to compare measured METs achieved during the various activities to those reported in the compendium of

physical activities. Although occasional equipment malfunction resulted in some missing MET data points, at least 24 subjects completed each activity. Data was analyzed using SPSS (PAWS Statistics, Version 18, Chicago IL). Data are reported as mean \pm SEM and significance was set at P<0.05.

Results

Subject characteristics are presented previously [11]. Briefly, the male (n=18) and female (n=10) stroke survivors were older (age: 60.4 \pm 1.6 years), obese (BMI: 31.5 \pm 1.1 kg/m²; body fat: 37.1 \pm 2.4%), and deconditioned (VO₂ peak: 19.0 \pm 0.98 ml/kg/min). They were 4.2 \pm 1.8 years post-stroke.

In the stroke survivors, measured resting metabolic rate (one MET) was 2.99 \pm 0.14 ml/kg/min, which was only 85% of resting compendium METs (P<0.01). However, the measured energy cost of mobility-related activities was ~1.25-1.50 fold greater in stroke (using 3.5 ml/kg/min as the denominator to determine measured METs) than compendium METs for all measures (P's<0.05), except floor sweeping, which was similar between groups (Figure 1). Stepping in place represented the activity with the greatest difference between measured and compendium METs.

Discussion

There is some debate as to whether 3.5 ml/kg/min adequately represents one MET across all populations. Our results suggest that using a MET equivalent of 3.5 ml/kg/min may overestimate RMR in stroke survivors. We have previously shown that measured RMR is 14% lower than predicted in chronic stroke survivors [14]. Our previous work also found that RMR in stroke survivors is related to total leg lean mass suggesting that muscle atrophy, which is common post-stroke [15], may play a role in declines in RMR. There is additional evidence that RMR is lower in those that are older and overweight [16], adding to the risk of a sedentary lifestyle after a stroke. This overestimation of RMR may result in underestimation of activity by reducing the ratio of activity to rest. Further, in stroke survivors, hemiparesis may increase the energy cost of mobility-related activities. From our selected mobility-related activities, we believe that floor sweeping is the activity least impacted by hemiparesis as it requires the smallest amount of lower extremity movement. Indeed, we did not observe differences in measured vs. compendium energy cost for floor sweeping. However, our results are like previous studies suggesting that the energy cost of activities dependent on lower extremity movement, including stepping in place and treadmill walking, are elevated in stroke survivors with chronic hemiparesis [2,3]. These data indicate that MET levels for lower level mobility provided in the compendium of physical activities are not applicable to chronic stroke survivors as they overestimate energy expenditure at rest and underestimate energy expenditure during periods of lower intensity mobility-related activity.

Patients with stroke spend more of their rehabilitation time focused on walking compared to all other activities [17]. However, physical activity recommendations after a stroke need to be customized to the ability of the patient since activity limitations extend years into the chronic phase of stroke recovery [18]. In healthy, older adults, a self-selected walking speed of ~2.0 mph is suggested as a speed that reflects the transition from light to moderate activity [19,20]. Our data suggest that this transition happens at a lower intensity (~1.0 mph at a 4% incline) in stroke survivors, highlighting the elevated energy cost for a

given task in stroke compared older, non-disabled adults. As this study is limited in sample size, we were unable to stratify by race or sex, both of which previously are shown to affect self-selected walking [21,22]. These data emphasize the need to assess factors that may influence functional impairment to promote physical activity after stroke.

Promotion of ambulation is important as walking ability reflects overall functional health [23]. Defects in walking distance remain the most striking area of difficulty among individuals with chronic stroke [24]. Studies suggest that aerobic exercise can improve cardiorespiratory fitness, physical function, and walking ability, and lower the energy cost of treadmill walking after a stroke [25-27]. Further, while unexamined in stroke, aerobic exercise can improve RMR in older adults [28,29]. Thus, stroke rehabilitation should focus on determining ways to increase aerobic exercise to offset sedentary behavior associated with hemiparesis.

In summary, our results suggest that stroke-specific compendium of physical activities are needed to adequately assess energy cost of lower intensity mobility-related activities in stroke survivors as the current compendium categories may underestimate activity related energy expenditure, especially if based upon the traditional MET=3.5 ml/kg/min at rest. Future studies are needed to determine how the energy cost of activities may be modified by lifestyle interventions in stroke survivors to best promote physical activity.

Acknowledgments

Our appreciation is extended to the volunteers who participated in this study. We are grateful to the medical team and exercise physiologists of the University of Maryland School of Medicine Division of Gerontology and Geriatric Medicine and Baltimore VA GRECC and MERCE for their assistance in this project. This study was supported by Veterans Affairs (VA) Merit, Senior Research Career Scientist, and CDA-2 Awards, NIH R01-AG030075, the National Institute on Aging (NIA) Claude D. Pepper Older Americans Independence Center (P30-AG028747), Baltimore VA Research Service, Geriatric Research, Education and Clinical Center (GRECC), Maryland Exercise and Robotics Center of Excellence (MERCE).

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