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Accelerometer cut-points derived during over-ground walking in persons with mild, moderate, and severe multiple sclerosis

Brian M. Sandroff [a], Barry J. Riskin [a], Stamatis Agiovlasitis [b], Robert W. Motl [a,*]

[a] Department of Kinesiology and Community Health, University of Illinois at Urbana-Champaign, United States
[b] Department of Kinesiology, Mississippi State University, United States

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ABSTRACT

Background: There has been increased interest in objectively quantifying time spent in moderate-to-vigorous physical activity (MVPA) using accelerometry as an outcome among persons with multiple sclerosis (MS). This requires development of a cut-point for interpreting the rate of accelerometer output based on its association with energy expenditure during physical activity.
Objective: The current study measured activity counts from a waist-worn accelerometer and energy expenditure based on indirect calorimetry during three speeds of over-ground walking for deriving cut-points for interpreting accelerometer output in persons with mild, moderate, and severe MS disability.
Methods: 54 participants with MS initially completed a neurological examination for generation of an EDSS score. Participants were then fitted with an ActiGraph model GT3X + accelerometer and a Cosmed portable metabolic system, and completed three, 6-minute walk (6 MW) tests that were interspersed with 10–15 min of rest. The first 6 MW was undertaken at a comfortable walking speed (CWS), and the two remaining 6 MW tests were undertaken above (faster walking speed) or below (slower walking speed) the participant's CWS in a counterbalanced order.
Results: The linear association between activity counts per minute and energy expenditure did not differ between persons with mild and moderate MS disability, but it was significantly different among persons with severe disability. This resulted in disability-specific cut-points for MVPA of 1980 and 1185 counts per minute for groups with mild/moderate disability and severe disability, respectively.
Conclusions: We believe that this research will facilitate a better understanding of time spent in MVPA across a broad range of MS disability.

1. Introduction

Persons with multiple sclerosis (MS) typically engage in less physical activity, particularly of moderate-to-vigorous intensity (MVPA), than the general population [1,2]. Indeed, fewer than 20% of persons with MS meet the recommended levels of MVPA (i.e., 150 min per week) necessary for public-health benefits [2]. This is a major concern given that physical inactivity is associated with an increased risk for negative health outcomes (e.g., subclinical atherosclerosis; [3]) in persons with MS, as well as a potentially debilitating downward spiral of physiological deconditioning and worsening mobility disability [4]. These concerns favor the design and implementation of interventions for increasing MVPA in this population, but require accurate measurement of meaningful physical activity metrics that have public-health significance for gauging intervention success.

There has been increased interest in objectively quantifying time spent in MVPA as a meaningful physical activity outcome among persons with MS using commercially-available accelerometers [5]. This is done based on 'cut-points' derived from the rate of counts per minute from accelerometers corresponding with 3 metabolic equivalents (METs) or more (i.e., MVPA). To that end, protocols developed for healthy adults [6] have been applied for generating cut-points to quantify time spent in MVPA based on accelerometer output in MS [1]. These researchers examined the association between rates of activity counts from two models of ActiGraph accelerometers and energy expenditure from indirect calorimetry across a range of treadmill walking speeds in 43 persons with seemingly mild-to-moderate MS, based on a median Patient-Determined Disease Steps (PDDS) score of 1 (range = 0–5), and 43 matched controls [1]. Overall, persons with MS had similar rates of activity counts, but expended significantly more energy than healthy controls across a range of speeds. This resulted in a steeper association between activity counts and energy expenditure in persons with MS than controls, and MS-specific cut-points for MVPA of 1723 and 1584 counts per minute for the ActiGraph model 7164 and GT3X accelerometers, respectively [1]. These cut-points have been applied

* Corresponding author at: University of Illinois at Urbana-Champaign, Department of Kinesiology and Community Health, 233 Freer Hall, 906 South Goodwin Ave., Urbana, IL 61801, United States. Tel.: +1 217 265 0886; fax: +1 217 244 7322.
E-mail address: robmotl@illinois.edu (R.W. Motl).

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for post-processing of free-living accelerometer data and quantifying time spent in MVPA based on counts per minute exceeding the appropriate threshold value [2].

One major limitation of that study involved the treadmill walking protocol. Treadmill walking results in different patterns of acceleration of the center of mass and energy expenditure than over-ground walking [7]. This could influence the accuracy of cut-points from treadmill walking for quantifying over-ground ambulatory physical activity that occurs in the real world among persons with MS. Another limitation of that study was the inclusion of persons with MS who seemingly had mild-to-moderate disability based on self-reported disability status, rather than the Expanded Disability Status Scale (EDSS; [8]) from a neurological examination. Such a level of disability was necessary given the constraints of the treadmill-walking paradigm. Disability status, however, has been associated with the energetic cost of walking [9,10] and might influence the association between accelerometer counts and energy expenditure, particularly in persons with severe disability. If correct, then one cut-point for quantifying time spent in MVPA might not be appropriate across the entire range of MS disability.

The current study further developed cut-points for quantifying time spent in MVPA from accelerometer output in persons with MS across a broader range of disability. To do this, we adopted an over-ground walking protocol [9] and measured rates of activity counts from an ActiGraph model GT3X+ accelerometer and energy expenditure based on indirect calorimetry from expired gas analysis using a Cosmed portable system in persons with mild, moderate, and severe MS disability, based on EDSS scores. We hypothesized that the cut-points for MVPA in the overall sample would approximate those previously generated using a treadmill walking paradigm, but that the cut-points would differ as a function of disability status, particularly in severe MS.

2. Methods

2.1. Participants

Persons with MS residing in the local community (i.e., within 60 min of our laboratory) who participated in previous laboratory studies were contacted via telephone and e-mail messages about this investigation of physical activity behavior. Participants were further recruited via referrals from a local neurologist. Those who expressed interest in the study underwent screening for inclusion criteria that included: (a) a neurologist-confirmed diagnosis of MS; (b) relapse-free during the previous 30 days; (c) ambulatory with or without assistance; (c) age between 18 and 64 years; and (d) absence of risk-factors for undertaking strenuous physical activity (e.g., cardiovascular diseases, diabetes, hyperlipidemia, and hypertension) based on the Physical Activity Readiness Questionnaire (PAR-Q; [11]). As we were interested in forming groups of persons with mild, moderate, and severe MS, prospective participants underwent a self-reported EDSS [12] over the telephone. The resultant score was not used in data analyses, but was used as a preliminary indicator of disability status for the purpose of recruiting disability subgroups of relatively equal size. We contacted 148 persons with MS, and 61 were uninterested in participating. The resulting 87 persons underwent screening, and 15 qualified for the study, but were unable to travel to our laboratory, and 9 persons were disqualified based on the presence of risk-factors for undertaking physical activity. Nine participants did not have usable energy expenditure data, resulting in a final analyzed sample of 54 persons with MS. There were 18 persons with mild MS disability, 20 persons with moderate MS disability, and 16 persons with severe disability.

2.2. Primary measures

2.2.1. Accelerometers

The rates of activity counts were measured by commercially-available ActiGraph model GT3X+ accelerometers (Health One Technology, Fort Walton Beach, FL). This model of accelerometer contains a solid state, digital accelerometer that generates an electrical signal proportional to the force acting on it along three axes; the current study only included counts from the vertical axis for consistency with previously derived cut-points [1]. The acceleration signal is sampled by a 12-bit analog-to-digital converter and stored in a raw format in the units of gravity (G's) with motion outside normal human movements rejected by a band-pass filter. The raw activity data are downloaded using the ActiLife 6 software and expressed as activity counts per unit time (i.e., counts per minute). We included five ActiGraph model GT3X+ accelerometers in the study and counterbalanced the application of the units. The accelerometers were initially calibrated by the manufacturer before the onset of this study, and we further calibrated the accelerometers before and after the study such that there was less than 10% variation in output across a 15-minute period of walking at 3.0 mph on a motor-driven treadmill. The accelerometers were initialized using the low-frequency extension feature as this increases sensitivity for capturing low frequency accelerations (i.e., slow walking) and makes the output directly comparable with output from the model 7164 accelerometer; this older model represents the most widely used output in the general population and in persons with MS [11,12]. The main outcome was activity counts per minute in the vertical axis averaged across the 6 MW tests.

2.2.2. Energy expenditure

Oxygen consumption (VO_2) was measured breath-by-breath using a commercially available portable metabolic unit (K4b2 Cosmed, Italy) during a 6 MW test that was performed over-ground in a rectangular hallway with four corridors. The O_2 and CO_2 analyzers of the portable metabolic unit were calibrated using known concentrations of gases, and the flowmeter was calibrated using a 3-l syringe (Hans Rudolph, Kansas City, MO). We expressed energy expenditure as VO_2 (ml/kg/min) over 30-second averages for both 1-minute before the 6 MW (i.e., resting VO_2) and over the entire 6 MW. Steady-state VO_2 was expressed as the average VO_2 value in ml/kg/min across the final 3 min (i.e., minutes 4–6; see Fig. 1) of the 6 MW tests.

2.2.3. Disability status

All participants underwent a neurological exam by a Neurostatus certified examiner who generated EDSS scores [8] for describing the sample and stratifying persons into three groups based on mild (EDSS of 0–3.5), moderate (EDSS of 4.0–5.5), and severe (EDSS of 6.0–6.5) disability status; these groupings are consistent with other research on ambulation in MS (e.g., [13]).

2.2.4. Gait

Participants completed two trials of walking at a self-selected pace across a 25-foot path with a 16-foot GAITRite™ electronic walkway (CIR systems, Inc.) embedded in the middle of the path for measuring gait outcomes. We recorded cadence (steps/min), step length (cm), base of support (cm), time spent in single support (percentage of gait cycle), and time spent in double support (percentage of gait cycle) among other variables provided by the GAITRite™. These variables were selected based on previously reported alterations of gait parameters in persons with MS [14]. We averaged the recorded values per variable across both trials.

2.3. Protocol

The procedure was approved by the University of Illinois at Urbana-Champaign Institutional Review Board and all participants provided written informed consent before beginning the study. Participants initially completed a demographic questionnaire, followed by a neurological examination for generation of an EDSS score. We then measured each participant's height and weight using a scale-stadiometer unit (Detecto model 3P7044, Webb City, MO), followed by completion of