Journal of the Neurological Sciences 361 (2016) 95–100

Contents lists available at ScienceDirect

Journal of the Neurological Sciences

journal homepage: www.elsevier.com/locate/jns

Step-rate cut-points for physical activity intensity in patients with multiple sclerosis: The effect of disability status

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ARTICLE INFO

Article history:
Received 7 October 2015
Received in revised form 13 December 2015
Accepted 17 December 2015
Available online 19 December 2015

Keywords:
Physical activity
Neurological disability
Measurement
Over-ground walking

ABSTRACT

Background: Evaluating the relationship between step-rate and rate of oxygen uptake (VO_2) may allow for practical physical activity assessment in patients with multiple sclerosis (MS) of differing disability levels.
Aims: To examine whether the VO_2 to step-rate relationship during over-ground walking differs across varying disability levels among patients with MS and to develop step-rate thresholds for moderate- and vigorous-intensity physical activity.
Materials and methods: Adults with MS ($N = 58$; age: 51 ± 9 years; 48 women) completed one over-ground walking trial at comfortable speed, one at 0.22 $m \cdot s^{-1}$ slower, and one at 0.22 $m \cdot s^{-1}$ faster. Each trial lasted 6 min. VO_2 was measured with portable spirometry and steps with hand-tally. Disability status was classified as mild, moderate, or severe based on Expanded Disability Status Scale scores.
Results: Multi-level regression indicated that step-rate, disability status, and height significantly predicted VO_2 ($p < 0.05$). Based on this model, we developed step-rate thresholds for activity intensity that vary by disability status and height. A separate regression without height allowed for development of step-rate thresholds that vary only by disability status.
Conclusion: The VO_2 during over-ground walking differs among ambulatory patients with MS based on disability level and height, yielding different step-rate thresholds for physical activity intensity.

1. Introduction

Physical activity is an important component of rehabilitation and health promotion for persons with multiple sclerosis (MS) [1–3]. Physical activity can contribute to the management of MS by reducing complications [4–6] and by improving mobility and quality of life [7,8]. However, patients with MS have lower physical activity levels than the general population [9,10]. Hence, there is a need to increase efforts of physical activity promotion in this population.

The health benefits of physical activity largely depend on the intensity at which physical activity is performed. In particular, significant health benefits result, if people perform at least 150 min of moderate-intensity or 75 min of vigorous-intensity aerobic activity during a week (i.e., public health guidelines); equivalent combinations of weekly moderate- and vigorous-intensity activity satisfy the guidelines [11]. These physical activity recommendations require a definition of what consists of moderate- and what vigorous-intensity physical activity. Most authorities define the thresholds for moderate- and vigorous-intensity physical activity as activity performed at 3 and 6 times the rate of oxygen uptake (VO_2) during rest, respectively [1]. The average resting VO_2 is generally considered to be 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$; thus, the moderate- and vigorous-intensity thresholds reflect activity at 10.5 and 21 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively [1]. The VO_2, however, cannot be easily monitored during daily activities because this requires bulky and expensive equipment. Consequently, rehabilitation and health promotion professionals must use indirect methods of monitoring intensity.

One such indirect and practical approach involves monitoring with pedometers or accelerometers the step-rate during walking, and it has been suggested that a step-rate of 100 $steps \cdot min^{-1}$ is a general heuristic cut-off for moderate-intensity physical activity [12,13]. Additional research has demonstrated that step-rate cut-offs vary as a function of height [14]. However, cut-offs developed for healthy people generally do not apply to patients with MS [15]. This is likely because persons with MS often have spasticity [16], gait alterations [17], or ambulation difficulties [18] that may influence the energetic cost of walking [19–23]. The level of disability further influences the energetic cost of walking in MS [15,24]. To that end, previous research has demonstrated different relationships between step-rate and VO_2, and different step-rate cut-offs for physical activity intensity between persons with and without MS [15]. That study further reported that step-rate cut-offs differed between participants as a function of walking impairment and

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http://dx.doi.org/10.1016/j.jns.2015.12.027
0022-510X/

height. The sample of that study, however, was relatively small and included only persons with MS who had minimal or mild walking impairment; thus, the results may not generalize to patients with MS with higher levels of disability. In addition, walking impairment was assessed subjectively with the Multiple Sclerosis Walking Scale-12. That study used treadmill walking, which has lower ecological significance for daily ambulation than over-ground walking. There is a need to address these limitations with further research.

This study examined if the relationship between VO_2 and step-rate during over-ground walking differed among ambulatory patients with MS who have mild, moderate, or severe neurological disability based on Expanded Disability Status Scale (EDSS) scores [25]. This study further developed new step-rate thresholds for moderate- and vigorous-intensity physical activity that vary based on disability status for individuals with MS. We hypothesized that VO_2 would be predicted by step-rate, disability status, and height, leading to different step-rate thresholds for activity intensity for ambulatory individuals with MS of varying disability levels.

2. Materials and methods

2.1. Participants

We targeted patients with MS residing within 60 min of our laboratory who had participated in previous studies or were referred from a local neurologist. Criteria for inclusion in the study were: (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 65 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 [26]. We contacted 148 persons with MS. Eighty seven expressed interest in participating and underwent screening for inclusion criteria. Nine persons were disqualified based on the presence of risk-factors for physical activity. Another 15 could not travel to our laboratory and were excluded. Five participants did not have any energy expenditure data because of technical problems with the portable metabolic unit, resulting in a final analyzed sample of 58 persons with MS. All participants with MS provided written informed consent.

2.2. Protocol

The procedure was approved by a University Institutional Review Board and was conducted following appropriate ethical standards. Each participant attended one laboratory session. Participants first completed a demographic questionnaire and then underwent 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). Thereafter, participants were fitted with the metabolic unit described below and sat quietly for 5 min. Following this rest period, participants completed three over-ground walking trials in a rectangular hallway 90 m in perimeter. Each trial lasted 6 min and was followed by 10–15 min of sitting, allowing nearly-complete rest. The first trial was conducted at the participant's comfortable walking speed (CWS). Another trial was conducted at a faster walking speed (FWS) and a third at a slower walking speed (SWS) than CWS. FWS and SWS were 0.5 mph ($0.22\ m \cdot s^{-1}$) faster than CWS and 0.5 mph slower than CWS, respectively. The order of the FWS and SWS trials were counterbalanced between participants. During the CWS trial, one researcher followed the participant rolling a distance-measuring wheel (MP301, Keson, Aurora, IL) outfitted with a pre-calibrated cycle computer (Velo 5, Cateye, Osaka, Japan). CWS was calculated based on the total distance walked over the 6 min. Speed during the FWS and SWS trials was controlled by having the participant follow a well-trained researcher who achieved the specified speed by rolling the measuring wheel and observing instantaneous speed on the cycle computer. We recorded total distance during each 6 min trial and computed the actual average speeds. This procedure has been previously used successfully for controlling walking speed in persons with MS [24,27].

2.3. Step-rate

During the three walking trials, a second researcher followed the participant and measured with a hand-tally counter the number of steps taken by the participant. Hand-tally counting is considered an accurate method of directly measuring steps and it is commonly used as the criterion against which other step-counting methods are compared [12,14]. Step-rate in $steps \cdot min^{-1}$ was determined as the total number of steps divided by the 6 min of each trial.

2.4. Rate of oxygen uptake

The VO_2 during the walking trials was measured breath-by-breath with a portable metabolic unit (K4b2, Cosmed, Italy). This system was calibrated prior to each testing session following the procedure specified by the manufacturer. Steady-state VO_2 was determined in $ml \cdot kg^{-1} \cdot min^{-1}$ as the average VO_2 over the last 3 min of each walking trial.

2.5. Disability status

A Neurostatus certified examiner performed a neurological exam with each participant and generated an EDSS score. This scale provides a standard measure of neurological disability in MS, and represents a summary score based on evaluation of functional systems and ambulation [25]. The sample was then stratified into three groups: (a) mild (EDSS of 0–3.5), (b) moderate (EDSS of 4.0–5.5), and severe (EDSS of 6.0–6.5) disability status. These groupings are consistent with prior research on ambulation in MS [27,28].

2.6. Statistical analyses

The relationship between VO_2 and step-rate was analyzed with multi-level modeling, accounting for the nesting of observations within participants (three trials nested within participants). The dependent variable was the VO_2 achieved during the walking trials. Fixed effects included step-rate, disability status (1 = mild; 2 = moderate; 3 = severe), and height. As further elaborated in the Results section, the effect of height appeared small; thus, we run 2 models—one with and one without height as a predictor. Potential random effects included the intercepts and slopes of the VO_2 to step-rate relationship across participants. Parameters were included in the model based on the difference in the -2 log-likelihood between models against a χ^2 distribution with 1 degree of freedom. Five participants (1 with mild; 2 with moderate; and 2 with severe disability) had a total of 7 missing values; these occurred either due to technical difficulties in monitoring VO_2 or due to inability of a participant to complete a walking trial. Importantly, multi-level modeling is advantageous for handling missing data [29]. Using the regression equation, we calculated the step-rate thresholds for moderate- and vigorous-intensity activity (i.e., step-rate at 10.5 and 21.0 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively) for participants with mild, moderate, and severe disability. We examined differences between the three disability groups in descriptive attributes, walking speeds, as well as VO_2 and step-rate across speeds with ANOVAs; when the effect of disability was significant post-hoc analyses (Tukey HSD) were performed. Statistical analyses were conducted using IBM SPSS Statistics 23 (IBM, Armonk, NY) and the alpha level was 0.05.