Annals of Physical and Rehabilitation Medicine xxx (2018) xxx–xxx

ELSEVIER

Available online at
ScienceDirect
www.sciencedirect.com

Elsevier Masson France
EM|consulte
www.em-consulte.com

Annals of Physical & Rehabilitation Medicine
SOFMER

Original article

Predicting the oxygen cost of walking in hemiparetic stroke patients

Q1 M. Compagnat [a,b,*], S. Mandigout [a], D. Chaporro [a,b], J.Y. Salle [a,b], J.C. Daviet [a,b]

Q2 [a] HAVAE EA6310 (Handicap, Aging, Autonomy, Environment), University of Limoges, Limoges, France
[b] Department of Physical Medicine and Rehabilitation, University Hospital Center of Limoges, Limoges, France

ARTICLE INFO

Article history:
Received 20 October 2017
Accepted 2 March 2018

Keywords:
Stroke
Walking
Oxygen cost
Speed

ABSTRACT

Objective: To verify the relation between spontaneous walking speed (Sfree) and oxygen cost of walking at Sfree (Cwfree) in post-stroke hemiparetic patients and to test the validity of a prediction model to estimate Cwfree based on Sfree.

Design: We included 26 participants (mean age 65.1 years [SD 15.7]) with mild to moderate disability after stroke who walked at Sfree using mobility aids if necessary for 6 min. The Cwfree was measured at a stabilized metabolic rate by indirect calorimetry with the Metamax 3B spiroergometry device. The relation between Sfree and Cwfree was analyzed by the correlation coefficient (r) and coefficient of determination (R2). The Cwfree prediction model was developed from a regression equation, then tested on a second population of 29 patients (mean age 62.1 years [SD 13.4]) with the same inclusion and exclusion criteria.

Results: For the 26 participants, the Sfree and Cwfree were highly correlated ($r = -0.94$ and R2 = 0.97), which allowed for formulating a regression equation and developing the Cwfree prediction model based on Sfree. The prediction model tests yielded accurate results (mean bias -0.02 mL.kg^{-1}.m^{-1}; 95% limits of agreement -0.31 to 0.26 mL.kg^{-1}.m^{-1}). The relation between Cwfree estimated by the model and measured by Metamax was high (R2 = 0.98).

Conclusion: Cwfree was strongly correlated with Sfree, which allowed for the development of a valid Cwfree prediction model. A practitioner could estimate the energy expenditure of walking for a patient without using an indirect calorimeter.

1. Introduction

Strokes are the worldwide main cause of acquired disability in adults [1]. Consequently, stroke patients are deconditioned and predisposed to a sedentary lifestyle [2], which adversely affects performance in activities of daily living and may contribute to heightened risk for recurrent stroke and supplementary cardiovascular diseases [3]. Physical exercise improves cardiorespiratory fitness, functional independence, walking ability and the ability to perform activities of daily living after a stroke [3,4]. However, the optimal amount and intensity of post-stroke fitness training remains unclear [4]. Monitoring the amount and intensity of physical activity a stroke patient performs is fundamental to ensure safety and generate benefits [3].

The oxygen cost of walking (Cw) is a marker of metabolic solicitation that quantifies the energy cost of walking after conversion of the oxygen volume into kilocalories [5]. However, the Cw at spontaneous walking speed (Sfree) — Cwfree — is extremely variable among individuals [5]. Measuring Cwfree in stroke patients requires the use of advanced instrumentation such as a respiratory gas exchange analyzer and is not commonly performed because of the cost of this device and the practical constraints in terms of the measuring protocol [6].

However, several authors have shown that the Cwfree is highly correlated with the Sfree. Zamparo et al. found a high correlation coefficient (0.92, $P < 0.001$) between Sfree measured over a 40-m loop and Cwfree measured by indirect calorimetry in 20 post-stroke hemiparetic patients [7]. Thus, Cwfree was closely associated with Sfree in hemiparetic stroke patients, and the authors could develop a regression equation for estimating Cwfree from Sfree [8]. Polese et al. reported that Sfree accounted for 81% of the Cwfree variance. Reisman et al. found a high correlation ($r = 0.86$, $P < 0.001$) between Sfree measured over 10 m and Cwfree measured by indirect calorimetry in 16 hemiparetic stroke patients [9]. This close relation between Sfree and Cwfree in hemiparetic stroke patients could allow practitioners to predict the Cwfree from the Sfree value, a reliable and easily measurable parameter in

* Corresponding author at: Department of Physical Medicine and Rehabilitation, University Hospital Center of Limoges in France, 2, avenue Martin-Luther-King, 87000 Limoges, France.
E-mail address: maxence.compagnat@icloud.com (M. Compagnat).

https://doi.org/10.1016/j.rehab.2018.03.001
1877-0657/

clinical practice [10]. Therefore, estimating the Cw would be simple without the need for a gas exchange measuring device.

The objectives of the study were to verify the relation between Sfree and Cwfree in hemiparetic stroke patients and to test the validity of a prediction model designed to estimate Cwfree based on Sfree.

2. Methods

2.1. Study design

We recruited 2 samples of participants, the first population used to explore the relation between Sfree and Cwfree. In case of a close relation between the 2 variables, we pursued the development of a regression equation to develop a prediction model of Cwfree based on Sfree. A second population was recruited to evaluate the validity of the model. We also compared Cwfree estimated by the prediction model and Cwfree measured by the Metamax 3B spiroergometry device. We ensured that the criteria for inclusion and exclusion were the same for both populations.

2.2. Participant selection

Participants were recruited in the Physical and Rehabilitation Medicine Department of our hospital. The inclusion criteria were:

- a single stroke in any area of the brain, except the cerebellum and brain stem, confirmed by brain imaging;
- ability to walk continuously for 6 min with or without mobility aids.

The exclusion criteria were acute cardiac or respiratory pathologies or decompensated chronic pathologies. Cardiac disorders were identified by complementary examinations usually performed at post-stroke assessment (i.e., electrocardiography and cardiac ultrasonography). We did not perform a stress test before the study.

The health professional responsible for the protocol informed the patients of the details of the protocol before registering their verbal consent. This consent was transcribed in the database. The research protocol was approved by the French ethics committee (No. CERNI 2015-01-13-57).

2.3. Hemiplegia evaluation

Motor impairment was evaluated by the Demeurisse motricity index [11]. This test quickly assesses a patient's motor impairment at 3 different points per deficient limb and is validated in stroke patients. A score is calculated from 5 levels of voluntary motor control on a scale to 0–100, a score of 100 considered healthy [11,12]. Spasticity was evaluated by the modified Ashworth scale [13]. Walking autonomy was assessed by the Functional Ambulation Classification modified [14]. Autonomy related to activities of daily living was evaluated by the Barthel index [15]. All these evaluations were performed by the same experimenter for all participants.

2.4. Equipment

O_2 consumption when walking was measured by indirect calorimetry with the breathing gas-exchange portable analyzer, Metamax 3B (Cortex Medical, Leipzig, Germany). The Metamax is a portable metabolic measurement system composed of a measurement module and a battery module. It measures gas volume by a bidirectional digital turbine. The O_2 and CO_2 concentrations are measured by using an electrochemical cell and an infrared analyzer. Oxygen flow (VO_2) and carbon dioxide flow (VCO_2) were calculated by standard metabolic algorithms based on the Haldane transformation [16]. Respiratory volume data and respiratory gas concentrations were transmitted live by telemetry to a computer. The system was paired to the Metasoft 3 software, v3.7.0 SR2.

The system was turned on for at least 20 min before each use and was calibrated before every test according to the manufacturer's recommendations. The gas analyzers were first calibrated by using a reference gas (14.97% O_2, 4.96% CO_2, balance N2: $\pm$ 0.02% absolute, Hong Kong Specialty Gases), then the calibration exposed to ambient air was checked. Additionally, volume calibration involved using a standardized 3-Lsyringe (5530 series, Hans Rudolph, Inc., Shawnee, KS, USA).

2.5. Experimental design

All participants performed the whole test under the same conditions. The Metamax was first placed on the patient. With the patient resting on a chair, gas exchanges were recorded for 6 min. Then, the patient was asked to walk for 6 min in a 40-m loop, with no obstacle or U-turn. This 6-min duration was chosen because about 4 min are required to achieve metabolic stability in individuals with chronic pathologies [17,18]. Several studies of Cw in post-stroke hemiparetic individuals have used a similar duration to obtain a stable metabolic state [7,9,19]. The main instruction for each patient was to maintain their Sfree for the duration of the test. Sfree was then calculated by dividing the distance walked by the time of the test (6 min).

2.6. Calculating Cwfree

Cwfree was calculated from the patient's O_2 consumption measured at a stabilized metabolic rate, defined by a variation in VO_2 lower than 2 $mL.kg^{-1}.min^{-1}$, as described in previous studies related to the oxygen cost of walking for post-stroke individuals [9]. To estimate Cwfree, we divided the VO_2 value at a stabilized metabolic rate per unit of time by Sfree. Therefore, Cwfree was expressed in milliliters of $O_2.kg^{-1}.m^{-1}$.

2.7. Statistical analysis

Our first objective was to evaluate the correlation between Cw and Sfree. Several authors have shown a high correlation between the two ($r = 0.8$–0.9, $P < 0.05$) in populations of fewer than 20 individuals [7,9,19]. Therefore, we considered we needed about 20 participants to demonstrate a statistically significant correlation. To validate the model, we considered that the average bias should be lower than 15%, with limits of confidence ($\pm$ 2 SD) of about 30%. The mean oxygen cost values were about 0.63 $mL.kg^{-1}.m^{-1}$ (95% confidence interval [CI], 0.53–0.72) [5]. Thus, the estimated mean bias was 0.1 $mL.kg^{-1}.m^{-1}$ (SD about 0.1 $mL.kg^{-1}.m^{-1}$). We used an alpha risk of 0.05 and a power of 80%. Using the formula provided by Bland–Altman, we estimated that we needed a sample of 32 participants to test the validity of the model [20].

Normally distributed data were analyzed by Anova and non-normally distributed data by a Mann–Whitney type of nonparametric test. Categorical data were analyzed by Chi^2 test. Correlation analysis of Sfree and Cwfree involved the Spearman coefficient (r) and the coefficient of determination (R2). The rule of thumb for interpreting the size of a correlation coefficient was 0.90 to 1.00, very high; 0.70 to 0.90, high; 0.50 to 0.70, moderate; 0.30 to 0.50, low; and 0.00 to 0.30, negligible [21]. The accuracy was analyzed by the mean bias and difference percentages. The association between the estimated and measured Cwfree was examined by

Please cite this article in press as: Compagnat M, et al. Predicting the oxygen cost of walking in hemiparetic stroke patients. Ann Phys Rehabil Med (2018), https://doi.org/10.1016/j.rehab.2018.03.001