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Stroke volume and cardiac output during 6 minute-walk tests are strong predictors of maximal oxygen uptake in people with stroke

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ABSTRACT

The 6-minute walk test (6MWT) is a field test commonly used to predict VO_{2peak} in people after stroke. Inclusion of cardiodynamic variables measured by impedance cardiography (ICG) during a 6MWT has been shown to improve prediction of peak oxygen consumption (VO_{2peak}) in healthy adults but these data have not been considered in people after stroke. This study investigates whether the prediction of VO_{2peak} can be improved by the inclusion of cardiovascular indices derived by impedance cardiography (ICG) during the 6MWT in people with strokeThis study investigates whether the prediction of VO_{2peak} can be improved by the inclusion of cardiovascular indices derived by impedance cardiography (ICG) during the 6MWT in people with stroke

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1 People diagnosed with stroke and receiving treatment at the Second People's Hospital, Shenzhen, China, were invited to participate in the study through in-hospital poster advertising. The inclusion criteria were: (1) age ≥ 18 years, (2) clinically diagnosed with ischemic and/or hemorrhagic stroke, (3) period since stroke diagnosis ranging from 3 to 12 months after diagnosis, (4) able to independently ambulate with or without an assistive device for ≥ 100 meters, (5) medically stable and with no significant limitation due to pain, and (6) able to clearly comprehend the exercise testing instructions.

2 People after stroke underwent in random order, a maximal cardiopulmonary exercise test

(CPET) and 6MWT in separate dates. The processes for 6MWT and CPET were explained, and signed informed consent was obtained.

3 Testing order was determined randomly by drawing lots

4 All participants were requested to avoid caffeine-containing products, nicotine, and alcohol at least 12 hrs before attending the laboratory

5 Variables recording - Cardiodynamic parameters including HR, SV, CO were recorded at one-second intervals by means of impedance cardiography (ICG) (PhysioFlow® PF07 EnduroTM Paris, France) during 6MWT and CPET. Oxygen saturation (SpO2) was recorded with the Heal Force pulse oximeter (POD-3, China). Systolic and diastolic blood pressure (SBP and DBP) was measured with the OMRON electronic blood pressure monitor (U30, China). Rate of perceived exertion (RPE) at the end of each test was recorded with the modified 0–10 Borg Scale.

6 6MWT - The 6MWT was performed in a 30-meter hospital hallway, following the standard protocol recommended by the American Thoracic Society (ATS). For each test, participants were asked to rest in a sitting position for 10 minutes before and after the 6MWT. The cardiodynamic parameters (HR, SV and CO) were measured using the ICG at one-second intervals during both tests. The SpO2 was recorded before and after each 6MWT. The SBP and DBP were measured at two-minute intervals during the 10-minute rest period, before and after each 6MWT. The RPE was recorded immediately at the end of each 6MWT.

7 CPET - Each participant also performed a progressive CPET in the hospital cardiopulmonary laboratory using a cycle ergometer (Ergoselect 200, Ergoline GmbH, Germany). Throughout the test, 12-lead electrocardiography was continuously recorded, and the participant was required to wear a mask and breathe through a calibrated volume sensor. Oxygen consumption, carbon dioxide consumption and respiratory exchange ratio (RER) were measured by the MasterScreenTM CPX, breath-by-breath metabolic cart (CareFusion, Germany). The gas analysis system was fully calibrated immediately before each test in accordance with the manufacturer's instructions. The HR, SV, and CO were also measured with ICG at one-second intervals during the CPET. The CPET protocol commenced with a rest period of 3 minutes sitting on the cycle ergometer to establish a steady state, then a 3-minute warm-up stage with pedaling without resistance. Participants were then required to pedal at increasing intensity of 4-8 W increments each minute, to ensure that the total exercise time remained in a range of 8-12 minutes. Participants were instructed to maintain a cycling speed of 55-65 revolutions per min. Strong verbal encouragement was given throughout the test. The test was terminated once the participant was unable to maintain the required pedaling rate despite encouragement, or should any signs of risk to health, as prescribed in the guidelines of the American College of Sports Medicine (ACSM) become manifest. Respiratory exchange ratio (RER) > 1.15 and Borg scores at the level "very hard" were used to signify a "maximal" exercise test performance. Participants were asked to rate their sensation of

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fatigue level immediately after the test using the modified Borg 0-10 scale administered during the 6MWT.

8 Impedance cardiography ICG - The PhysioFlow® PF07 is a portable, non-invasive device that adopts real-time wireless monitoring of morphology-based impedance cardiography signals via a blue tooth USB adapter to measure HR, SV and CO at one-second intervals. Electrodes were applied as described by Tonelli and colleagues. The HR was derived directly from the ECG, SV was calculated from the cardiac ejection waveform and the CO was obtained by the multiplication of the SV and HR. ICG data from the last 10 seconds of the 6MWT were averaged as the peak cardiodynamic variables of the 6MWT, and data for CPET were computed similarly.

9 Data analysis - All data were analyzed using IBM SPSS Statistics for Windows, Version 25.0 (Armonk, NY: IBM Corp). Demographic data and clinical characteristics for all participants were summarized using descriptive statistics. Variables of interval-ratio data meeting a normality assumption were compared using the independent t test for gender difference. The Chi-square test was used for the analysis of gender specific categorical data. HR, SV, CO were averaged every 10 seconds. Differences in HR, SV, CO recorded at rest, at the peak of CPET and at the end of the 6MWT were analyzed using repeated-measures ANOVA. The associations between measured VO2peak and recorded variables (including 6MWD, HR, SV, CO) at the end of 6MWT and at the end of the CPET were analyzed by Pearson's correlation coefficients.

10 Three sets of multiple linear regression analyses were primarily performed to explore the optimal predictor variables of VO2peak. The first regression equation was built by 6MWD as the single variable predicting VO2peak. The second regression equation was generated using BMI, age, gender, duration after stroke, 6MWD, plus HR, SV and CO recorded by ICG at the end of the better performed 6MWT as predictors for VO2peak. The third regression equation utilised the same variables as in the 2nd equation but with peak HR, SV and CO measured during CPET. The stepwise backward regression method was adopted to determine the significant predictor variables to be retained in the regression equations. The appropriateness and precision of the regression parameters were evaluated with the squared multiple correlation (R2), the standard error of estimate (SEE) as well as the 'SEE/meanVO2peak' ratio, which was expressed as a percentage (SEE%). The predicted residual sum of squares (PRESS) statistic was computed to estimate the degree of R2 shrinkage (Rp2) when the VO2peak regression equation was used for cross-validation across similar but independent samples. PRESS-derived Rp2, SEEp and SEEp% for each regression model were compared. Two further analyses were conducted to examine the unique contribution of changes in HR or SV to any changes in CO, during 6MWT and CPET; forced entry regression method with HR change and SV change as predictor variables were used.

11 Sample size estimation - A sample size of at least 54 participants were required, with 8 predictor variables (ag, gender, BMI, duration after stroke, 6MWD, HR, SV, CO) modelled for estimated effect size of 0.3, a level of 0.05 and power of 0.08.

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