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Validation of 6 min step test and 4-m gait speed in children: A randomized cross-over study

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ABSTRACT

Introduction: Even if 6-min walking test (6MWT) is the criterion standard for functional exercise performance evaluation, new field tests are required as practical alternative. This study aims to establish the validity of the 6-min step test (6MST) and the 4-m gait speed (4MGS) in children.
Method: It is a randomized cross-over trial. Sixty one healthy children from 6 to 12 years were recruited. 6MWT, 6MST and 4MGS were randomly performed on three consecutive days. Pulsed oxygen saturation (SpO2), heart rate (HR), dyspnea (VAS) and fatigue (PCERT) were used as outcomes.
Results: The distance walked during 6MWT was correlated to the number of steps during 6MST ($r = 0.320$; $p = 0.013$) and not correlated to 4MGS ($r = -0.074$; $p = 0.575$). No correlation between number of steps during 6MST and 4MGS ($r = -0.129$; $p = 0.332$) was found. HR was lower than the theoretical maximal HR after the tests. The increase in HR was significantly higher for 6MST and significantly lower for 4MGS than for 6MWT and it was higher for 6MST than for 4MGS. Dyspnea and perceived exertion were lower after 6MWT than after 6MST and higher than after 4MGS. They were also higher during 6MST than during 4MGS.
Conclusion: The three field tests are feasible in children. The 6MST and 4MGS are not valid surrogates to 6MWT in healthy children for functional exercise performance evaluation. Moreover, the cardio-respiratory response differs between the three tests.

1. Introduction

Exercise training is increasingly being used in the treatment of children with various diseases (cardiac disease, cystic fibrosis (CF), asthma or neuromuscular diseases [1–4]), thereby justifying the importance of functional exercise performance evaluation. In adult, the six minute walking test (6MWT) is the criterion standard for this purpose [5]. Even though children were not in the scope of the recent technical standard co-published by the European Respiratory Society and the American Thoracic Society [6], validity and reliability of the 6MWT in children have long been verified [7–10]. Moreover, 6MWT has been routinely used in children in various conditions [11–13].

Recently, new field tests appeared and were proposed as practical alternative in adults. The objective was to reduce length or to counteract the 30m-hallway requested for the realization of this test in clinical routine [14]. Indeed, different step tests [15], clinically useful and requiring a minimum of space and technical expertise were proposed. A self-paced 6-min step test (6MST) was demonstrated to be easy to perform, reliable and reproducible to estimate exercise perfomance and exercise-related oxyhaemoglobin desaturation in interstitial lung disease adult patients [16]. More recently, Kon et al. validated 4-m gait speed (4MGS) in chronic obstructive pulmonary disease (COPD) patients [17]. This test has the same advantages than the 6MST and it has been established as a marker of exercise performance in the elderly [18]. If these tests were documented in adults, there is lack of studies on the application of these tests in children which justifies the studies. We hypothesize that these tests could be used to measure the functional exercise performance in place of the 6MWT similarly to adults even if they could imply different behaviors in children than in adults. The number of steps and the gait speed could reflect the walked distance.

The principal aim of this study was to establish the validity of the 6MST and the 4MGS as a tool to measure functional exercise performance in children without cardio-respiratory limitation by correlating them to the 6MWT. Secondly, the similar outcomes were compared

Abbreviations: 6MWT, 6-min walking test; 6MST, 6-min step test; 4MGS, 4-m gait speed; SpO2, pulsed oxygen saturation; HR, heart rate; PCERT, Pictorial Children's Effort Rating Table

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between these three tests.

2. Method

2.1. Subjects

Healthy children (6 to 12 years old) were recruited in an elementary school in January 2014. The inclusion criterion was the participation in the national physical education program at school after the annual medical investigation. The exclusion criteria were to be diagnosed of a chronic lung, cardiac or neuromuscular disease, at risk of- or overweight (BMI higher than 85th percentile for children of the same age and sex) [19] or a motor disability based on parents' answer to a standardized questionnaire. The subjects were free of physical activity during one hour preceding the experiments.

The study was approved by the regional Ethic Committee in Cliniques universitaires Saint-Luc and Université Catholique de Louvain in Brussels in 2010 (BE403201317636) and registered with ClinicalTrials.gov (NCT02318238). Parents of the children and children provided their written inform consent prior to the experiment.

2.2. Design of the study

It was a cross-over randomized design. The children performed the three investigated field tests on three consecutive days at the same time of the day. Field tests randomization was performed by a computer generated random number list (www.randomizer.org). The analysis was blinded.

2.3. Field tests

All the field tests were performed by the same trained examiner, independent of the analysis.

2.3.1. 6MWT

6MWT was carried out in a straight, unobstructed and flat corridor utilizing the outlined protocol by ATS for adult patients and validated in healthy children by Li et al. [7]. Children were instructed to walk as far as possible for 6 min between two marks separated by 30 m. During the test, standardized sentences were pronounced. Walked distance was measured and expressed in absolute and in relative values [20].

2.3.2. 6MST

6MST was performed on a 20 cm-high single-step device without handles. The test followed the same guidelines than the 6MWT regarding the encouragements [6]. Children were instructed to step up and down the device as fast as possible in a 6-min period. The cadence was free. The physical performance in the test was determined by the total number of ascents and descents.

2.3.3. 4MGS

4MGS was performed in a flat unobstructed hallway with a 4 m distance marked out with tape based on a previously used protocol in adults [17]. A demonstration test was showed to each participant prior to starting the test. Children were positioned with the toes touching the exactly first mark. They were instructed to walk to the next mark at the usual speed and chronometer was stopped when the first foot completely crossed it. Standardized encouragements were given. The test was repeated without rest and the 4MGS was calculated from the faster test. Gait speed was expressed in meters per second.

2.4. Outcomes

Pulsed oxygen saturation (SpO2) and heart rate (HR) were measured with a finger pulse oximeter (Onyx, Nonin, USA). Theoretical HR was calculated with the specific equation for children (208-(0.7 × age) [21]). The variability of these parameters during the test and during the rest period was calculated by the difference between initial and final values divided by the initial value. Symptoms of dyspnea and fatigue were evaluated through the visual analogue scale (VAS) and the Pictorial Children's Effort Rating Table (PCERT) respectively. These measures were recorded at rest, immediately after the test and after a two-minute recovery.

2.5. Statistical analyses

The sample size determination was based on the detection of a 0.70 correlation coefficient between two field tests with a power of 80% and an alpha level of 0.05. The number of participants required for the study was determined to be 52.

Data were computed using SPSS 23.0 (IBM software) for Windows. Descriptive analysis was performed for demographic parameters and for results of the three tests. It was presented as mean, standard deviation and confidence interval, or median and minimum and maximum after verifying the normality of the distribution. Normality of the distribution was verified by Kolmogorov-Smirnov test. Similar parameters between the three tests were compared by an One-way repeated measures analysis of variance. Tukey method was used for post-hoc comparisons. Correlation between the number of steps (6MST) or the gait speed (4MGS) and the walked distance (6MWT) were calculated by Pearson's correlation coefficient to verify the validity of these two first measurements as a surrogate to 6MWT. A lower p-value than 0.05 was considered as significant.

3. Results

Seventy-four children were eligible but sixty-one children (age = 8.0 ± 1.3 y.) were recruited and randomized. One child did not perform all tests for missing the appointment (Fig. 1). All the children succeeded the completion of the three tests. Demographic parameters of the children are illustrated in Table 1. All children had normal demographic values.

The walked distance (6MWT) was 91 ± 11% of predicted value (512 ± 62 m). The number of steps (6MST) performed was 190 ± 24. The gait speed (4MGS) was 0.86 ± 0.13 m/s. Walked distance was significantly but weakly correlated to the number of steps ($r = 0.320$; $p = 0.013$) (Fig. 2) but not correlated to the 4MGS ($r = -0.074$; $p = 0.575$). There was also no correlation between 6MST and 4MGS ($r = -0.129$; $p = 0.332$).

Cardio-respiratory parameters measured before and after the tests are shown in Table 2. They were similar before the three tests. At the end of the test, HR was lower than the theoretical maximal HR. No desaturation was observed after the test. The increase in HR was significantly higher for 6MST and significantly lower for 4MGS than for 6MWT and it was higher for 6MST than for 4MGS. The variation of saturation was significantly different between the three tests. Dyspnea and perceived exertion were lower after 6MWT than after 6MST and higher than after 4MGS. They were also both higher during 6MST than during 4MGS. The difference in perceived exertion after 6MWT and 6MST is explained by the distribution of the measures (Fig. 3).

4. Discussion

This study showed that the 6MWT, 6MST and 4MGS are feasible in children and that the number of steps from the 6MST, but not the 4MGS, is correlated to the distance walked during the 6MWT. In addition, we observed that the cardio-respiratory response differs between each of the three tests in our sample of children 6–12 years old. Based on HR response to each test, the 6MST is 217% more demanding than the 6MWT and the 4MGS is 33% less demanding.

The assessment of the individual's functional performance is clinically important, as it provides an evaluation of the respiratory, cardiac,

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