The 6-Minute Stepper Test cannot be used to assess the functional exercise capacity in healthy children from 6 to 12 Years Old

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ABSTRACT

Background: Background: Assessing functional exercise capacity in children has become increasingly important. This capacity may be assessed by different tests including submaximal test. The gold standard submaximal test in children is the six-minute walking test (6MWT). The main aim of this study was to establish the concurrent validity of the six-minute stepper test (6MST) to assess the functional exercise capacity. The secondary objectives were to compare the change in cardiorespiratory parameters between 6MST and 6MWT, and to determine the feasibility of the 6MST in healthy children. Methods: 53 healthy children were included in this crossover randomized trial. Subjects underwent the 6MST and 6MWT in a random order. The primary outcome was the number of steps during 6MST and the 6-minute walking distance (6MWD). The secondary outcomes were the pulse oxygen saturation and heart rate. Results: 6MWD and number of steps were not correlated (r=0.103; p=0.46). There was a significantly greater increase (p<0.001) in pulse heart rate values during the 6MWT than the stepper test ($46.8 \pm 17.5\% vs 31.1 \pm 18.3\%$). Moreover, no correlation between heart rate changes was found in both tests (r=0.139; p=0.32). Pulse oxygen saturation was clinically unchanged in both tests. All children were able to complete the 6MST. Conclusion: We were not able to demonstrate the concurrent validity of the 6MST to assess the functional exercise capacity. Moreover, 6MST and 6MWT have different cardio-pulmonary demands. However, we found that the 6MST is feasible in healthy children from 6 to 12 years old.

KEYWORDS: 6MWT, stepper test, children, physical functional performance, cardiopulmonary exercise test

Introduction

Assessing functional exercise capacity is important regarding respiratory, cardiac, musculoskeletal and metabolic systems. This capacity is usually assessed by aerobic maximal or submaximal tests. The establishment of a training program adapted to subjects is also based on the results of these tests [1]. As most activities of daily living are submaximal, submaximal field tests are as important as maximal tests as a complement, or substitute for subjects who are not able to perform a maximal test. Submaximal tests increase heart rate without reaching the predicted maximal heart rate[2]. The six-minute walking test (6MWT) is the standard field test used in order to evaluate functional exercise capacity. It is easy to perform, has been validated in children [3, 4], and better reflects real life than other walking [5], but is sometimes difficult to perform because it requires a long corridor [6]. Many studies validated alternative to the 6MWT such as the six-minute step test, 4-m gait speed or the sit-to-stand test [1, 7, 8, 9]. Stepper test is one of them. It can be performed whatever the environment because it requires only a small area and the use of a stepper, and allows the measurement of physiological responses during its execution [10]. It may be conducted under various protocols. To follow the American Thoracic Society statement for the

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6MWT, a six-minute stepper test was developed. This setting is valid and reproducible in adults [11, 12]. To our knowledge, there is currently no study on its application to children. Moreover, it is well known that the validation process can be influenced by the age of the subjects for these tests [13]. The aim of this study was to establish the concurrent validity of the 6-minute stepper test (6MST) in order to measure their submaximal functional exercise capacity by correlating them to the 6MWT in children from 6 to 12 years old without cardio-pulmonary restriction. The secondary objectives were to compare the change in cardiorespiratory parameters between these two tests, to determine the feasibility of the 6MST in healthy children and to verify the correlations between anthropometric data and the results of the tests.

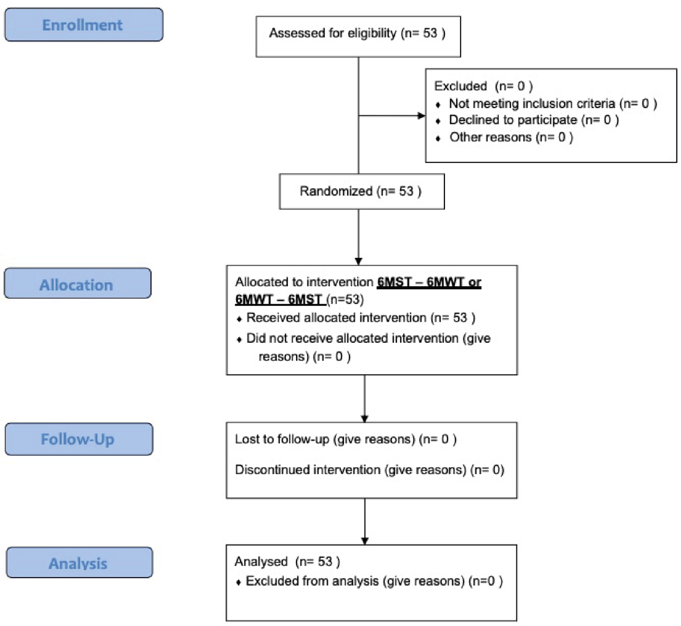

Figure 1 Figure 1: consort flow diagram

Method

Subjects

Healthy children from 6 to 12 years old were prospectively recruited in a scout camp in July 2019 and in an elementary school from Wallon Brabant in November and December 2019. The recruitment was performed by sending a letter to all parents and stopped when the required sample size was obtained.

Inclusion criteria were: accepted to physical education class during school year (with medical approval), and the absence of motor impairments. Exclusion criteria were: bodyweight exceeding norms for the age group (>95th percentile), presence of a chronic pulmonary, cardiac, or neuromuscular disease. The study was approved by the regional Ethics Committee of the Cliniques universitaires Saint-Luc and Université Catholique de Louvain in Brussels in April 2019 (BE403201940195).

All participants and their parents gave their written informed consent.

Design

It was a crossover randomized trial and it followed the Consort statement. The children achieved both field tests 24 hours apart. The order in which the tests were conducted was randomized using the randomizer.org website. They were naïve for the tests.

Field test Tests were performed under supervision of the same qualified examinator. Subjects had not engaged in strenuous physical activity for one hour prior to the testing procedure.

Six-minute walking test (6MWT) Subjects were instructed to walk for the longest distance possible during six minutes and could stop if necessary but should resume as soon as possible. The hallway was flat and free from obstacles. Two cones were placed 30 meters apart and the subject had to go back and forth between those cones. Instructions and stimulation were standardized following the American Thoracic Society statement(6), as it is frequently done with this test in children [7, 14, 15]. Only one test was performed as no training is required in children [16].

Six-minute stepper test (6MST) Subjects were instructed to perform as many steps (downwards, alternating between left and right leg) as possible on the stepper (Domyos MS100, Décathlon, France) for six minutes. The device was positioned in front of a wall which could be used as a support in case of instability or loss of balance. The experimenter provided identical instructions for all participants.

Outcomes

The main outcomes were walking distance (in meters) and number of steps, for the 6MWT and the 6-minute stepper test, respectively. Those outcomes were analyzed by the same examiner. The distance was expressed in absolute and relative values. Predicted walking distance was calculated for the 6MWT using the equations of Geiger et al. [14]. The number of steps was expressed in absolute value and normalized by minute. There is no predicted value for the 6MST. The pulse oxygen saturation (SpO2) and heart rate (HR) were measured using a finger-pulse oximeter (Onyx, Nonin, USA). Maximal predicted heart rate was determined by using the equation (208-(0,7 x age))[17]. Those values were analyzed for both tests before the test (i), instantly after the six minutes of exercise (f), and after two minutes of recovery (r).

Table 1 Demographic data of subject

Parameters	Values
Gender (F/M)	28/25
Age (years)	8.7 ± 1.8
Weight (kg)	30.2 ± 8.2
Height (m)	1.4 ± 0.1
BMI (kg/m^2)	15.7 ± 1.9

Values are expressed as means ± SD[95%CI]
BMI: body mass index.

Statistical analysis

Sample size determination was based on screening of a correlation coefficient of 0.7 between the two tests, with a power of 80% and an alpha level of 0.05. Number of required participants was 53. Data were analyzed using SPSS 27.0 for Windows (IBM Software). A descriptive analysis was done for the demographic parameters and results of both tests. These analyses were described using the mean, standard deviation and a confidence interval of 95% given the law of large numbers. The correlation between the number of steps and the walked distance was computed using Pearson's correlation coefficient to verify the concurrent validity of the stepper test. Similar parameters between both tests were compared using Student's paired t-test given the law of large numbers and were correlated together. The correlations between the results of the tests and the anthropometric data were tested. Statistical testing may also be used to verify the statement regarding the difference in variability.

Table 2 Comparison of cardio-pulmonary parameters of the tests (mean ± standard deviation [confidence interval of 95%]).

Cardio-pulmonary parameters	6MWT	6MWT	p-value
HRi (bpm)	97.0 ± 11.5 [93.9; 100.2]	98.4 ± 12.8 [94.9; 101.9]	0.268
HRf (bpm)	141.9 ± 20.1 [136.4; 147.4]	128.7 ± 22.6 [122.5; 134.9]	0.001*
HRr (bpm)	109.7 ± 16.6 [105.2; 114.2]	103.9 ± 15.0 [99.9; 108.0]	0.001*
HRD(f-i)/i (%)	46.8 ± 17.6 [42.1; 51.5]	31.1 ± 18.3 [26.1; 36.2]	0.001*
HRD(r-f)/i (%)	-22.3 ± 9.6 [-24.9; -19.6]	-18.0 ± 11.5 [-21.2; -14.9]	0.027*
SpO2i (%)	98.5 ± 0.75 [98.3; 98.7]	98.4 ± 0.9 [98.2; 98.7]	0.606
SpO2f (%)	98.0 ± 1.0 [97.8; 98.3]	98.1 ± 0.9 [97.9; 98.4]	0.579
SpO2r (%)	98.4 ± 0.8 [98.1; 98.6]	98.4 ± 0.7 [98.2; 98.6]	0.855
$SpO2D_{(f\text{-}i)/i}$ (%)	-0.4 ± 1.0 [-0.7; -0.12]	-0.3 ± 1.2 [-0.6; 0.0]	0.501
SpO2D(r-f)/i (%)	0.3 ± 1.1 [0.0; 0.6]	0.3 ± 1.0 [0.0; 0.5]	0.704

p-value represents results from Student's paired t-tests. HR: heart rate; SpO_2: pulse oxygen saturation; i: initial; f: final; r: recovery (two minutes post-exercise); $HRD_{(f\text{-}i)/i}$: increase of HR after exercise reported to HR_i; $HRD_{(r\text{-}f)/i}$: decrease of HR after recovery reported to HR_i; $SpO_2D_{(f\text{-}i)/i}$ (%): SpO_2 variation between before and after test; $SpO_2D_{(r\text{-}f)/i}$ (%): SpO_2 variation between instant after the test (f) and following recovery (r).

A p-value threshold of 0.05 was used for determining statistical significance.

Results

Participants

Fifty-three children had to be recruited for the study. No children had to be excluded after recruitment. All children successfully completed the tests, none withdrew from the study or experienced an adverse event during the protocol (**Figure 1**). Demographical parameters of the subjects are summarized in (**Table 1**).

Results of tests

All 53 subjected succeded succeeded in performing both tests. The mean distance in the 6MWT was $613.2 \pm 65.2m$ (595.5 to 630.5) which means $100.7 \pm 11.8\%$ of the predicted value. The mean number of steps was 309.3 ± 122.1 (276.2 to 341.9) which means $51.6 \pm 20.4/min$. The walked distance and the number of steps were not correlated (r=0.103; p=0.463). The results of 6MWT were less variable (c_v = 0.106) than the results of stepper test (c_v = 0.395).
The cardiopulmonary parameters (SpO2 and HR) of both tests are summarized in Table 2. The pulse heart rate increased in both tests (p<0.001) and these changes (with respect to initial heart rate) were different between 6MWT and 6MST (p<0.001). Moreover, no correlation was found between pulse heart rate changes in both tests (r=0.139; p=0.32). All pulse heart rates were lower after the tests than the maximal predicted heart rate. In other words, heart rate increased without achieving maximal predicted heart rate in both tests. The pulse heart rate recovery after exercise (reported to initial pulse heart rate) was also different between the 6MWT and 6MST (p= 0.027).
The correlation with anthropometric data were analyzed for both tests. Age, height, weight and BMI were correlated with 6MST ((r=0.729 (p<0.01), r=0.696 (p<0.01), r=0.719 (p<0.01), and r=0.473 (p<0.01)) but not with 6MWT ((r=0.139 (p=0.32), r=0.032 (p=0.82), r=0.147 (p=0.29), and r=-0.103 (p=0.46)).

Discussion

The aim of this study was to verify the concurrent validity of the 6MST in healthy children from 6 to 12 years old without cardio-pulmonary impairment to measure the submaximal functional exercise capacity by correlation with the 6MWT. The children were able to perform the 6MST but the number of steps performed during the 6MST was not correlated with the walked distance during the 6MWT. Furthermore, a higher cardiac demand was measured during the 6MWT than during the 6MST with no correlation between these two cardiac demands (r=0.139; p=0.32). This would indicate that the 6MST does not assess the functional exercise capacity in healthy children from 6 to 12 years old and that it cannot be used as a substitute for the 6MWT in this group of children.
In contrast with the findings of the current study, a correlation between the number of steps performed during various stepper tests and the walked distance during the 6MWT was found in adults [10, 12, 21, 22, 20]. An explanation for this discrepancy might be the different body weight influences on stepper and walking tests. Indeed, those with lower body mass (such as children in the present study) have trouble to push on the stepper. In our study, weight values were correlated with the results of 6MST but not with 6MWT. This might be due to the hydraulic cylinders under the foot pedals of the stepper, which creates a stress resistance during simulated stair climbing. This resistance cannot be adapted and the children with a lower weight may have had greater difficulty pushing on the stepper than the others and thus performed a smaller number of steps. However, results from the 6MWT indicated that body weight was not correlated with walked distance. It confirms the poor correlation previously observed by Geiger [14] between weight and walked distance and explaining the use of only height in the predictive equation for the distance.
The observed differences in cardio-respiratory parameters between the 6MST and the 6MWT in our study were similarly observed in adults. Pichon et *al.* explained this difference in adults by different factors [21]. Indeed, he hypothesized that "the body was supported during the 6MST, that walking was probably a more challenging situation for postural control, or that the lower limb muscular strain was different between stepping and walking". In children, postural control has been widely studied. Authors generally agree that postural control develops in a non-linear manner through to fourteen years of age [23, 24, 25]. Some studies have even highlighted this greater need for postural control during walking than standing still [25, 26]. It can be hypothesized that this is due to the greater displacement of the center of gravity during walking. To our knowledge, the difference in lower limb muscular strain

Table 3 Results from seven studies analyzing demographic data (mean ± standard deviation) and HR results from 6MWT and either step test or 6MST.

References	Tests	Population	Age (years)	Weight (kg)	Height (m)	HR changes between the start and the end of the test	
						Absolute value (bpm)	Normalized values (bpm/1m)
Bohannon et al. (2015)[8]	6MWT	189 participants	55.2 ± 16.8	73.0 ± 15.4	1.67 ± 0.1	NS but sig. higher HR at the end of 3-min step test than 6MWT	NA
	3MStT						
Reychler et al. (2018)[7]	6MWT	74 healthy children	8.0 ± 1.3	28.7 ± 6.2	1.31 ± 1.0	+22.5 ± 14.6	+3.8 ± 2.4
	4mGS					+7.4 ± 6.0	+1.2 ± 1
	6MStT					+48.9 ± 28.6	+8.2 ± 4.8
Balfour-Lynn et al. (1998)[18]	6MWT	85 children with cystic fibrosis	12.3	NS	NS	+24.0	+4
	3MStT					+38.0	+12.7
Aurora et al. (2001)[19]	6MWT	28 children with moderate-to-severe CF lung disease	13.7	NS	NS	+18	+3
	3MStT					+30	+10
Delourme et al. (2012)[20]	6MWT	84 subjects with various diffuse interstitial lung disease	56.0 ± 1.5	NS	NS	+34	+5.7
	6MST					+48	+8
Pichon et al. (2016)[21]	6MWT	62 COPD subjects	61.8 ± 9	NS	NS	NS but sig. higher HR at the end of 6MST than 6MWT	NA
	6MST						
Chéhère et al. (2016)[22]	6MWT	31 subjects with interstitial lung disease	61 ± 10	82 ± 15	1.7 ± 1.0	NS but sig. higher HR at the end of 6MST than 6MWT	NA
	6MST						

4mGS: four-minute gait speed; 6MWT: six-minute walking test; 6MST: six-minute Stepper test; 3MStT: three-minute step test; COPD: chronic obstructive pulmonary disease; CF: cystic fibrosis; bpm: beats per minute, NS: not specified; NA: no application

between stepping and walking observed in adults has never been verified in children.
In a recent study, children performed 31.7 steps/min during a step test consisting of stepping up and down a stair. Moreover, this test was 217% more demanding than the 6MWT [7]. While Borel et *al.* argued that the stepper and the step test were exchangeable in adults this does not appear true for children [27]. In our study, children performed steps at a greater rate than that observed by Borel et *al.* (51.6 ± 20.4 steps/min) highlighting this difference between stepper and step test. Based upon these observations, we would infer that the performing steps on the fixed step is more time consuming than performing steps on the stepper device, and that it is more demanding. In our study, the HR demand was higher. Furthermore, there was a greater increase in pulse heart rate values in the 6MWT than in the stepper test. As expected, pulse oxygen saturation remained clinically unchanged in our study, whatever the tests, and stayed in the normal range for a healthy population (97-100%). The HR demand found in other studies comparing the 6MWT with the 6MST appear similar to our results [7, 18]. Three other studies performed in adults reported that 6MST was more demanding than 6MWT [21, 22, 20], which is in contradiction with our findings. The hypothesis that BMI plays a role in the 6MST results might be the reason for its lower cardiac demand in children compared with 6MWT. Indeed, children might have to wait for the step to go back down to make another step. Bohannon and colleagues described this weight influence in the stepper test results in adults [8].
As already discussed, age, weight, height and BMI were correlated to the 6MST result. However, those parameters were not correlated to the 6MWT result even if children achieved 100.7% of the predicted value. Geiger et al., who evaluated the 6MWD in healthy children from 3 to 18 years old highlighted that 50% of 6MWD variability was explained by the age. The other 50% may be justified by physical fitness, coordination, motor skills or even motivation [14]. This last point might be the explanation for the lack of correlation between anthropometric data and 6MWD in this study.
Since all subjects were able to complete the 6MST, the test is feasible in healthy children aged from 6 to 12 years old. Unfortunately, due to the lack of validity, its clinical utility has yet to be determined. However, given it's relative simplicity and potential for use in various settings, the 6MST may be of interest for evaluating children with cardio-pulmonary diseases.

Limits

The limitations of the study are related to the fixed resistance of the stepper. In this study, the stepper had hydraulic cylinders, which induced a mechanical resistance. It would be interesting to repeat the experiment with other types of steppers, such as a stepper with electromagnetic braking. The advantage of this stepper is the possibility of modulating the resistance intensity, and It may be more adapted to measurements on children. Moreover, the choice of the 6MWT for reference values might also be discussed as the gold standard for assessing physical capacity is the cardiopulmonary exercise test. However, this choice was also performed in many studies because the 6MWT is considered as the reference for the functional exercise capacity.

Conclusion

In conclusion, the concurrent validity of the 6MST to assess the functional exercise capacity was not verified in children from 6 to 12 years old. Moreover, both the 6MST and the 6MWT have different cardio-pulmonary demands. However, the 6MST is feasible in these healthy children.

Clinical message

- The 6 minutes stepper test cannot use to assess the functional exercise capacity in children
- This test differs from the 6MWT in cardio-pulmonary demands

Statement and declaration

Authors' contribution

The authors confirm contribution to the paper as follows:

- Gregory Reychler: Conceptualization; Methodology, Formal analysis; Investigation; Writing - Original Draft; Supervision
- Hélène Absil: Methodology, Formal analysis; Writing - Review & Editing
- Alice Gillain: Methodology, Formal analysis; Writing - Review & Editing
- Gilles Caty: Methodology; Writing - Review & Editing

Competing Interests

All authors declare they have neither financial nor non-financial interests.

Disclosure statement

All authors declare they have neither financial nor non-financial interests.

Ethics

The study was approved by the regional Ethic Committee in Cliniques universitaires Saint-Luc and Université Catholique de Louvain in Brussels in April 2019 (BE403201940195).

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