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Letter to the editor

Predictive model for the 1-minute sit-to-stand test in healthy children aged 6 to 12 years

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Dear Editor,

The increasing importance of exercises as medicine in adults and children implies the evaluation of functional exercise capacity. The 6-min walk test (6MWT) is the reference test [1]. However, other field tests [sit-to-stand test (STST), step test, shuttle test etc.] have been developed to offer complementary information or to overcome the barriers related to resources needed for the 6MWT, such as a long hallway, the need for a second repeat of the test and the time constraints to perform the test.

For practical reasons, the STST is one of the most frequently used in children, mainly with neurological disease. It is quick to perform and requires only a chair, a small floor space and a stopwatch. The concurrent validity and reliability of the 1-min STST to evaluate the heart rate (HR) response to exercise have been recently verified in healthy children [2]. However, its clinical usefulness is still limited because of lack of predicted values in a healthy pediatric population as compared with adults. Such predictive values are necessary to identify individuals with impairment.

The aim of this study was to provide a predictive model for the 1-min STST in healthy Caucasian children by using demographic and cardiorespiratory outcomes easily measured before or after the STST.

A cohort of healthy children from 6 to 12 years old was recruited in one elementary school between September and November 2017. As unique inclusion criterion, the children had to participate in the national physical education program at school for which an annual medical investigation is required in Belgium. The exclusion criteria were a diagnosis of chronic lung, cardiac or neuromuscular disease; being overweight (body mass index greater than the 85th percentile for children of the same age and sex) [3] or a motor disability based on parents' answers to standardised questions. Children with invalid cardiorespiratory results (lack of stable signal) at the end of the STST were not included.

Approval for the study was obtained from the local ethics committee of the Cliniques universitaires Saint-Luc and Université Catholique de Louvain in Brussels (B403201629739). The study was registered at ClinicalTrials.gov (NCT03670511) and was conducted, according to the Declaration of Helsinki. Parents and children gave their written informed consent before the beginning of the study.

The Transparent Reporting of a multivariable prediction model for Individual Prognosis Or Diagnosis (TRIPOD) was followed for the study [4]. After a learning test (repetitions of a movement until the children could perform it correctly) to account for the learning effect [2], the children performed the 1-min STST with an interval of 15 min between both tests. All tests were supervised by the same trained physiotherapist and performed with a standard chair without arm rests (chair height 46 cm for children taller than 140 cm and 32 cm for children shorter than 140 cm or without both feet on the ground). Standardised instructions were given to the children before the test without any other encouragement. Children were asked to completely stand up and sit down with hands on the hips as many times as possible during 1 min.

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The outcomes used were the number of completed repetitions at the end of the STST, HR and pulse oxygen saturation (SpO_2) (Onyx, Nonin, Plymouth, MN, USA). HR was expressed in absolute value and in percentage of theoretical maximal HR with the specific equation for children [210-(0.65 × age)] [5]. The change in HR while performing the STST was calculated by the difference between initial (HR_i) and final (HR_f) values divided by the initial value.

The sample size was calculated based on the determination of the mean sit-to-stand repetitions in children at 5% type of 1 error and 1-repetition precision and 6-repetitions standard deviation, based on the previous validation study of this test [2]. The estimated number of participants required was at least 138.

Data were analysed with SPSS 25.0 (IBM) for Windows. Descriptive analysis of demographic parameters and STST results were performed. Continuous data are expressed with mean (SD). We calculated the number of repetitions during STST for each sex on the basis of an assumed onset of puberty at 9 and 12 years for girls and boys, respectively (prepuberty, 6–8 and 6–11 years). The effect size was calculated by Cohen's $d_s = 2 * t/\sqrt{n}$. A multivariate analysis was performed with a backward elimination procedure by multiple linear regression. The interdependence of the parameters was verified by Pearson's correlation. The *P*-value to remove a variable was set to 0.20 and that to re-enter a variable was set to 0.05.

We included 238 of the 307 recruited children in the analysis (Table 1). Of 8 children excluded, 5 were chronically treated for a respiratory disease and 3 did not want to participate after the training test. Another 61 were excluded because of inability to measure cardiorespiratory parameters immediately at the end of the test.

The mean (SD) number of repetitions was 50.3 (13.3) [95% CI: 48.6–52.0] for the entire cohort and was significantly higher for boys than girls ($P < 0.001$) despite no anthropometric differences between the sexes (Table 1). This male versus female difference was observed before and after puberty: prepuberty [mean (SD) 52.3 (13.5) (49.5–55.1) vs. 46.3 (12.1) (95% CI 43.1–49.3); $P < 0.001$] and puberty [62.9 (9.5) (58.4–67.3) vs. 47.1 (12.4) (44.1–50.2); $P < 0.001$]. The HR_f was 60% (13) of the theoretical maximal HR.

Multiple regression analysis demonstrated a significant association between number of repetitions and sex, age, weight and HR_f (Table 2). Age and weight were correlated ($r = 0.643$; $P < 0.001$). Model 1 including sex, age, weight and HR_f explained 28% of the STST variance (medium effect size). Model 2 including sex and HR_f explained 24% of the STST variance. The predicted equation for STST was derived from model 1: $STST_{pred.} = 0.218 \times HR_f$ (b/min) + 8.458 × sex (1 for boys and 0 for girls) –0.334 × weight (kg) + 1.545 × age (years) + 17.465. We observed a 1.5-increase in number of repetitions per 1 additional year of age.

This study is the first to report the expected number of repetitions in the 1-min STST in children 6 to 12 years old and allows for determining the predicted values for this test, which is necessary to interpret the results of this test, and is easy to perform in routine clinical practice. We identified an association between number of repetitions and age, sex and HR_f in this age group. These outcomes are easy to obtain.

We observed a sex effect related to number of repetitions during the STST. This finding is not surprising because the 6MWT is also influenced by sex in children [6]. The sex effect was neither related to the anthropometric parameters nor to puberty. The height was not correlated with the number of repetitions, contrary to the distance walked during the 6MWT [6,7]. Leg length is probably a more sensitive indicator of STST repetitions than height. Indeed, the number of sit-to-stand movements was previously related to leg length in young people [8] and height of the chair [9].

The association between greater HR_f and larger number of STST repetitions probably highlights a more intense effort performed by the children. This association was previously found with the walked distance in the 6MWT in children [7].

With these predicted values, the STST result for any child can be now interpreted. For example, a 10-year-old boy (40 kg) performing 40 repetitions with an HR of 100 beats/min at the end of the 1-min STST has reached 80% of the theoretical performance because the expected number of repetitions for these data is 50. The chosen model explains 28% of the variability of the number of repetitions in healthy Caucasian children, which is similar to the model fitted for the same test in adults [10].

The strengths of this study are the large sample size and the homogeneity of the sample in age. However, the study has some limitations. Firstly, we did not take into account the effect of children's intrinsic motivation [11], although the number of children included in

Table 1
Characteristics and cardiorespiratory outcomes for the sit-to-stand test (STST) for children in the study.

	All $n = 238$	Girls $n = 126$	Boys $n = 112$	Cohen's d_s	Girls vs. boys *P* value
Age (years)	8.7 (2.2)	8.9 (2.0) [8.5–9.2]	8.6 (2.3) [8.1–9.0]	0.14	0.31
Height (cm)	139.6 (13.9)	140.7 (13.4) [138.4–143.1]	138.4 (14.5) [135.7–141.2]	0.17	0.21
Weight (kg)	34.8 (10.9)	35.5 (10.8) [33.6–37.4]	34.0 (10.9) [31.9.4–36.0]	0.14	0.27
BMI (kg/m^2)	17.4 (3.0)	17.6 (3.2) [17.0–18.1]	17.3 (2.9) [16.8–17.8]	0.10	0.46
STST (repetitions)	50.3 (13.3)	46.7 (12.3) [44.5–48.8]	54.4 (13.4) [51.9–56.9]	0.60	< 0.001
SpO_2 (%)	97.2 (1.6)	97.3 (1.5) [97.0–97.6]	97.1 (1.6) [96.7–97.4]	0.17	0.20
HR_i (bpm)	86.7 (18.0)	87.6 (18.9) [84.2–90.9]	85.6 (17.0) [82.6–89.0]	0.10	0.33
HR_f (bpm)	123.5 (26.4)	125.3 (27.1) [120.5–130.1]	121.5 (17.0) [116.7–126.3]	0.15	0.89
$\Delta HR_{i\text{-}f}$ (%)	46.1 (36.9)	46.5 (35.9) [40.2–52.8]	45.7 (38.3) [38.5–52.8]	0.02	0.37

Data are mean (SD) and 95% confidence intervals. BMI: body mass index; HR_i: initial heart rate; HR_f: final heart rate; SpO_2: pulse oxygen saturation.

Table 2
Stepwise regression analysis for predicting the number of repetitions during the STST.

	R^2	Beta	Standard error	Beta standardised	*P* value
Model 1	0.287				< 0.001
Intercept		17.47	4.4		< 0.001
Sex		8.46	1.48	0.32	< 0.001
Age		1.55	0.46	0.26	0.001
Weight		−0.33	0.10	−0.27	< 0.001
HR_f		0.22	0.03	0.43	< 0.001
Model 2	0.243				
Intercept		21.27	3.75		
Sex		8.462	1.52	0.32	< 0.001
HR_f		0.203	0.03	0.401	< 0.001

HR_f: final heart rate.

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our study is probably sufficient to reflect the overall behaviour of the population. Furthermore, the intrinsic motivation of children in the STST may be of lesser impact than in the 6MWT because of the shorter duration of the former test. Secondly, we did not assess the physical activity level of the children in our study. Again, because the sample was large and consisted of all eligible children from a conventional school, we assumed that they represented the normal population in terms of physical activity. Thirdly, a large number of children were excluded because of the inability to immediately measure the cardiorespiratory outcomes with pulsed oximetry at the end of the STST. Children were excluded to ensure true cardiorespiratory values. A similar proportion was found in a previous study (38% of children) [12]. In fourth place, this predictive model is culturally specific to Belgian children.

In conclusion, this study is the first to determine predicted values for the 1-min STST in healthy Caucasian children. The proposed model to predict the number of repetitions during the STST in children 6 to 12 years old is related to age, sex and HR measured at the end of the test. On the basis of this model, the predicted values of the number of repetitions have now been determined for this category of children.

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Author contributions

GR and MC contributed to conception, design of the work and acquisition, analysis and interpretation of data; drafting the work and revising it for important intellectual content; NMM, WP, NA, and GC participated in conception of the work and analysis and interpretation of data; revising the work for important intellectual content. All authors gave final approval of the version to be published and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Disclosure of interest

The authors declare that they have no competing interest.

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