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ORIGINAL RESEARCH

Prediction equation of peak oxygen uptake for the modified shuttle test in healthy adolescents

Equação de predição do consumo máximo de oxigênio para o shuttle test modificado em adolescentes saudáveis

Ecuación de predicción del consumo máximo de oxígeno para el shuttle test modificado en adolescentes sanos

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ABSTRACT | Given the gap in the literature regarding the peak of oxygen consumption (VO_2peak) for adolescents of both sexes, this study aimed to propose an equation to predict the VO_2peak in healthy adolescents using the Modified Shuttle Test (MST). This is a cross-sectional study with 84 healthy adolescents between 12 and 18 years old, female and male. The MST is an external paced test, in which the speed increases at each minute. Two MST were performed with at least 30 minutes of rest between them. The test with the longest walked distance was considered for analysis. VO_2 was directly monitored by an open circuit spirometry. Mean age was 14.67±1.82 and the walked distance was 864.86±263.48m. Variables included in the prediction equation were walked distance and sex, explaining the VO_2peak variability of 53% during MST performance. The prediction equation for VO_2peak with the MST was: predicted VO_2peak=18.274+(0.18×Distance Walked, meters)+(7.733×Sex); R^2=0.53 and p<0.0001 (sex: 0 for girls, 1 for boys). This MST equation, proposed to predict VO_2peak in healthy adolescents of both sexes, can be used as a reference to assess exercise capacity in healthy adolescents and to investigate cardiopulmonary function in adolescents with reduced functional capacity.

Keywords | Oxygen Consumption; Modified Shuttle Test; Functional Capacity; Adolescent.

RESUMO | Dada a lacuna na literatura quanto à equação de predição do pico de consumo de oxigênio (VO_2) para adolescentes de ambos os sexos, o objetivo deste estudo é propor uma equação para predizer o VO_2pico em adolescentes saudáveis utilizando o *shuttle test* modificado (MST). Trata-se de um estudo transversal realizado com 84 adolescentes saudáveis entre 12 e 18 anos, do sexo feminino e masculino. O MST é um teste de campo ditado por um sinal sonoro que indica o aumento da velocidade a cada minuto. Dois MSTs foram realizados com pelo menos 30 minutos de descanso entre eles. O teste com a maior distância percorrida foi o considerado para análise. O VO_2 foi monitorado diretamente por uma espirometria de circuito aberto. A média de idade foi de 14,67±1,82 anos, e a de distância percorrida foi de 864,86±263,48m. As variáveis

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incluídas na equação de predição foram distância percorrida e sexo, que explicaram 53% da variabilidade do VO_2pico durante a realização do MST. A equação de referência para o VO_2pico previsto com o MST foi VO_2pico predito=18,274+(0,18×Distância percorrida, em metros)+(7,733×Sexo); R^2=0,53 e p<0,0001 (sexo: 0 para meninas, 1 para meninos). A equação do MST proposta para predizer o VO_2pico em adolescentes saudáveis de ambos os sexos pode ser usada como referência para avaliar a capacidade de exercício em adolescentes saudáveis e investigar a função cardiopulmonar em adolescentes com capacidade funcional reduzida.
Descritores | Consumo de Oxigênio; Shuttle Test Modificado; Capacidade Funcional; Adolescente.

RESUMEN | Dada una laguna en la literatura con respecto a la ecuación para predecir el consumo máximo de oxígeno (VO_2) en adolescentes de ambos sexos, el objetivo de este estudio es proponer una ecuación para predecir el VO_2máximo en adolescentes sanos usando el *shuttle test* modificado (MST). Se trata de un estudio transversal, realizado con 84 adolescentes sanos con edades entre 12 y 18 años, de ambos sexos. El MST es una prueba de campo dictada por una señal sonora que indica el aumento de velocidad cada minuto. Se realizaron dos MST con al menos 30 minutos de descanso entre ellos. Para el análisis se consideró la prueba con mayor distancia recorrida. El monitoreo del VO_2 fue realizado directamente por espirometría de circuito abierto. La edad media fue de 14,67±1,82 años; y la distancia recorrida, de 864,86±263,48m. Las variables incluidas en la ecuación de predicción fueron la distancia recorrida y el sexo, que explicaron el 53% de la variabilidad del VO_2máximo durante la realización del MST. La ecuación de referencia para el VO_2máximo predicho con el MST fue VO_2máximo previsto=18,274+(0,18×Distancia recorrida, en metros)+(7,733×Sexo); R^2=0,53 y p<0,0001 (sexo: 0 para chicas, 1 para chicos). La ecuación MST propuesta para predecir el VO_2máximo en adolescentes sanos de ambos sexos puede utilizarse como una referencia para evaluar la capacidad de ejercicio en adolescentes sanos y para investigar la función cardiopulmonar en adolescentes con capacidad funcional reducida.
Palabras clave | Consumo de Oxígeno; Shuttle Test Modificado; Capacidad Funcional; Adolescente.

INTRODUCTION

Functional capacity has been evaluated in clinical practices to provide parameters for the prescription and elaboration of exercise programs, with information about exercise tolerance under different health conditions and prognosis of morbidity and mortality[1,2].

Cardiopulmonary exercise tests with direct analysis of oxygen consumption are the gold standard to measure functional capacity[3]. However, the analysis requires high costs, specialized laboratory, and trained professionals. Moreover, simple and secure field tests with reference equations are widely used to assess the functional capacity and predict peak oxygen uptake (VO_2peak). Due to its easy applicability and execution, the modified version of the Shuttle Test (MST)[4] started to be implemented in different health conditions[5-7] and in healthy individuals[8].

The use of MST to assess the functional capacity in children with chronic diseases or in healthy conditions is already well established in literature[9]. Previous studies described different reference equations to predict the walking distance or the VO_2peak of children and adolescents during the MST, as well as of patients with cystic fibrosis[10], asthma[11], and adolescents with obesity[12].

Although previous studies described an equation to predict the VO_2peak of healthy adolescents, the inclusion criteria were restricted to male adolescents[13]. Thus, there is a gap regarding the VO_2peak prediction equation for adolescents of both sexes. Therefore, this study sought to propose an equation to predict the peak of oxygen consumption (VO_2peak) in healthy adolescents using the Modified Shuttle Test (MST).

METHODOLOGY

Design and participants of the study

This is a cross-sectional study from secondary data, which included healthy adolescents, from public and private schools in the city of Diamantina/MG and the children of the employees of the Universidade Nove de Julho (UNINOVE, São Paulo/SP, Brazil). Data were collected from April 2013 to May 2014 in UNINOVE, and from February 2018 to August 2019 in the Universidade Federal dos Vales do Jequitinhonha e Mucuri (UFVJM, Diamantina/MG, Brazil). The written informed assent was obtained from adolescents and the written informed consent was obtained from 18 years old participants and from parent or guardian of UNINOVE and UFVJM.

Inclusion criteria were adolescents from 12 to 18 years old and full term birth (>37 weeks of gestation). Exclusion

criteria were any health condition that could interfere with performing a physical exercise (informed via parents' report), e.g., any chronic or acute neurological, orthopedic, respiratory, cardiac, or endocrine disease. Moreover, adolescents who misunderstood the test and reported practicing regular physical exercise more than twice a week were also excluded.

Protocol of the study

All assessments were obtained during two visits at the Exercise Physiology Laboratory of the Universidade Federal dos Vales do Jequitinhonha e Mucuri (UFVJM), Diamantina/MG, Brazil, and at the Physiology Laboratory of the Universidade Nove de Julho, São Paulo/SP, Brazil, by trained researchers. On the first day, the familiarization with the test was carried out and the corporal composition was evaluated. For this assessment, the volunteers' weight and height were measured with a platform mechanical scale (110 F, Welmy, São Paulo, Brazil) accurate to 0.1kg and the body mass index (BMI) was estimated as weight÷height[2,14]. On the second day, two MST were performed with at least 30 minutes of rest between tests.

Modified shuttle test

MST was carried out on a flat ground, repeatedly covering 10m around a marking of two cones, placed 0.5m from each endpoint. The walking (or running) speed required for the participant was dictated by a beep played from a sound box. At every minute the walking speed was increased by 0.17m/s. The test finished when the adolescent was unable to reach the extremities two consecutive times, that is, if the individual needed to stop due to fatigue or breathlessness. As suggested by the literature, we used the modified protocol of 15 levels (1,500m)[15] to evaluate healthy participants, thus the volunteers could walk and run if they were able to. During the test, laps were recorded and the total distance walked was measured in meters[9].

Tests were performed two times with at least 30 minutes of rest between them. The best test, the one with the longest distance walked, was considered for analysis. A third test was performed when the difference between tests was greater than 40m[15].

Cardiorespiratory measurements

All procedures were performed by trained professionals. The heart rate was measured continuously by a cardiac monitor (POLAR RS800sd) and the blood pressure was measured by a mercury sphygmomanometer cuff and stethoscope, at the beginning and at the end of the test. The heart rate was registered as absolute value and as percentage of the maximum predicted value (HRmax). The maximum predicted HR was estimated as 208 (0.7×age)[16].

VO_2 was continuously monitored via direct analyzes by an open circuit spirometry (telemetry system of the K4b2® gas analyzer) (Cosmed, Rome, Italy) or VO_{2000} (MedGraphics Corporation®, St. Paul, MN, USA). The individuals breathed while wearing the face mask of the device. Collected data was transferred by radio to a computer near the test site. At the end of the test, the VO_2peak was used for analyzes. VO_2 peak rate (mL/min) was expressed as relative rate (mL/kg/min).

Statistical analysis

Statistical analysis was performed with SPSS statistical package version 25 (Chicago, Illinois). Shapiro–Wilk test was used to verify the normality of the data. Data showed parametric distribution and were expressed as mean±standard deviation (SD). Pearson correlation coefficient was used in the independent variables (distance walked, weight, age, height, BMI) and in the dependent variable (VO_2 peak), to select independent variables for the multiple regression analysis (stepwise) and to develop the predictive equation. The categorical variable sex was dichotomized, with boys equal to 0 and girls equal to 1, thus enabling the use Pearson's correlation with the dependent variable VO_2peak. Multicollinearity between independent variables was tested in this model. The conditional interaction between distance walked and sex was also tested. The difference in the distance walked between boys and girls was analyzed using an independent-sample t-test. The probability of a type I error was established as 0.05 for all tests.

Sample size calculation

Sample size was estimated with the equation: N>50+(8×m), where m was the number of independent variables included in the final equation[17]. A minimal sample of 66 individuals was included with α=0.05 and β=0.2. Considering that other possible correlations were evaluated, we decided to include more subjects. The sample size was estimated with the minimum of two independent variables that would be included in the final VO_2peak equation. Our sample consisted of 84 individuals

reaching more than the minimum number of individuals for a model with two independent variables.

RESULTS

In total, 84 individuals–34 girls and 50 boys–participated in this study. Table 1 shows the characteristics of the individuals. Boys reached greater distances during MST compared to girls (934.94m±281.46 m vs 761.80m±196.43 m, respectively, p=0.003). Moreover, boys reached higher values of VO_2peak (boys: 42±8.26 mL/kg/min and girls: 32.10±7.42mL/kg/min, p<0.0001) and predicted percentage for the HR(max) (boys: 95.21±6.98 % and girls: 87.32±8.78 %) when compared to girls (p<0.0001).

Table 1. Characteristics of the participants

Characteristics	Total group (n=84)	Boys (n=50)	Girls (n=34)	P-value
Age (years)	14.29±2.42	14.30±1.75	15.20±1.82	0.02
BMI (kg/m^2)	20.58±3.91	19.87±2.74	20.78±3.09	0.16
Weight (kg)	53.93±12.59	52.32±9.72	53.95±10.34	0.46
Height (m)	1.61±0.11	1.61±0.10	1.60±0.07	0.61
Walked distance (m)	864.86±263.48	934.94±281.46	761.80±196.43	0.003
VO_2 peak (mL/kg/min)	38.57±9.54	42.98±8.26	32.10±7.42	<0.0001
HR max (% predicted)	92.01±8.64	95.21±6.98	87.32±8.78	<0.0001

Values presented as mean±SD. BMI: body mass index; HR: heart rate.

We found a significant correlation between VO_2peak and distance walked (r=0.63; p<0.001) and sex (r=0.56; p<0.001). There was no significant correlation with weight (r=–0.26; p=0.40), age (r=0.81; p=0.22), height (r=0.90; p=0.20), and BMI (r=–1.13; p=0.118).

Walked distance and sex explained 53% (R^2=0.53, p<0.0001) of the variance in VO_2peak with a model of stepwise linear multiple regressions (Table 2). There was no multicollinearity between variables since interactions between variables did not persist in the final model.

Table 2. Predictor variables from multiple linear regression analysis for distance walked in the Modified Shuttle Test

	Unstandardized coefficients (B)	SE	P-value
Constant	18.81	2.803	<0.0001
Distance walked	0.018	0.003	<0.0001
Sex	7.733	1.537	<0.0001

The VO_2peak reference equation based on the MST performance for health adolescents is: predicted VO_2peak=18.274+(0.18×Distance Walked, meters)+(7.733×Sex); R^2=0.53 and p<0.0001 (sex: 0 for girls, 1 for boys).

DISCUSSION

Direct analysis of VO_2 can be unfeasible for clinical practice, thus this study developed a reference equation to predict the VO_2peak of adolescents of both sexes during the modified MST. Our data showed that, together, walked distance and sex explained 53% of the variance in VO_2peak.

Previous data of our group study showed that in healthy male adolescents only the distance walked explained the variation of 43% of the VO_2peak during the MST[13]. Walked distance is the main measure outcome of the MST, thus the better the cardiorespiratory performance, the greater the walked distance. Therefore, the VO_2peak is significantly correlated and influenced by walking distance[18,19]. These results corroborate with previous studies that also demonstrated the influence of the walked distance in the prediction of VO_2peak in the MST of adults and children and adolescents with cystic fibrosis[10] and asthma[11].

As expected, sex was also included in the VO_2peak prediction equation. In this study, boys walked more than girls. The sex difference has been described as a factor that can influence changes in body composition, showing the importance of including these variables in a prediction equation for adolescents. Boys have much greater increase in lean body tissue and less body fat during puberty. These factors, associated with hormonal issues[20] can benefit the performance condition of the male sex compared to the female sex.

Menarche is related to body composition, chemical exposure, and insulin resistance in girls[21-23]. The growth period starts earlier in girls, whereas for boys it lasts longer[24,25]. The difference between fat-free mass, lean mass, and percentage of body fat is more noticeable in adolescence, when girls have a higher percentage of body fat than boys and boys have a greater amount of fat-free mass[20]. Healthy girls show a decrease in bone mass around the age of 16[26]. Before 14 years of age, boys and girls differ little in their performance on a variety of motor tasks, including running speed. With puberty, much greater differences occur in neuromuscular responses and explosive activities, mainly due to a plateau in girls' performance[27].

However, the measures of BMI did not influence the VO_2peak in this study. Our data showed no difference between boys' and girls' height and weight and, consequently, BMI. Different variables such lean body mass and body fat could be analyzed to verify difference between sex and a prediction equation; however, this would be less feasible since these variables are more complicate to evaluate than sex and walked distance. Normal body composition was not correlated to VO_2peak, even with studies showing that being overweight affects functional capacity[28,29].

Moreover, age did not influence the prediction of VO_2peak, since a stabilization of aerobic performance occurs in youth. Adolescents' performance improves linearly with age and tends to achieve a plateau when they are 14 years old[28,30]. In this study, the average age for both sexes was over 14 years old and the data were homogeneous and did not influence in the VO_2peak.

In a previous study, other independent variables were used in a different proposed equation for the six-minute walk test, including percentage of heart rate and forced expiratory volume in the first second[18], which seems to be less feasible. The variables used in the present equation were sex and walked distance, two simple independent variables obtained during the assessment of rehabilitation.

This study included a group of sedentary adolescents, thus the equation might not apply in different populations.

CONCLUSION

In conclusion, an equation for the MST to predict VO_2peak in healthy adolescents of both sexes was proposed. This equation is a feasible tool for clinical practice and can be used to assess exercise capacity in healthy adolescents and to investigate cardiopulmonary function in adolescents with reduced functional capacity.

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