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ORIGINAL ARTICLE

Estimation of cardiorespiratory fitness from the Six-Minute Walk Test in schoolchildren

Estimación de aptitud cardiorrespiratoria a partir de la Prueba de Caminata de Seis Minutos en escolares

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What do we know about the subject matter of this study?

Cardiorespiratory fitness is low in children and adolescents. Exercise capacity can be assessed with the six-minute walk test. Studies have elaborated equations to predict the distance covered. None propose equations to predict cardiorespiratory fitness in our context.

What does this study contribute to what is already known?

The six-minute walk test is an instrument that is easy to apply and has a low cost. Applying the six-minute walk test to assess cardiorespiratory fitness in the school setting is plausible. The best prediction models for cardiorespiratory fitness included distance, age, weight, height, heart rate, and body mass index.

Abstract

Cardiorespiratory fitness can be assessed by direct, indirect, maximal, and moderate effort, running, cycling, or walking methods. **Objective**: To predict maximum oxygen consumption ($\dot{V}O_2max$) from the six-minute walk test in schoolchildren**. Patients and Method:** 459 students were included, 215 were male and 244 were female, aged 11.9 ± 1.3 years. Basic anthropometry and cardiorespiratory fitness were measured using field tests. Multivariate equations were developed to predict the $\dot{V}O_2max$ using the R® Commander v. 4.2.2 software ($p < 0.05$). **Results:** The best model predicting $\dot{V}O_2max$ include distance walked in the six-minute walk test, heart rate recovery, age, height, body weight

Keywords:
Cardiorespiratory Fitness;
Oxygen Consumption;
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($\dot{V}O_2max$ [L·min^{-1}] = - 0.0902 + (- 0.0464 × age) + (0.0002 × distance) + (- 0.0019 × HR) + (0.5843 × height) + (0.0353 × weight), R^2 = 0.76; error = 0.25 L·min^{-1})), and also body mass index ($\dot{V}O_2max$ [L·min^{-1}] = - 0.6152 + (0.0399 × age) + (0.0933 × BMI) + (0.0005 × distance) + (- 0.0022 × HR), R^2 = 0.57; error = 0.34 L·min^{-1})), both with $p < 0.001$. **Conclusions:** Cardiorespiratory fitness can be estimated based on basic anthropometry and performance on the six-minute walk test.

Introduction

Cardiorespiratory fitness has declined in recent years in Latin American children and adolescents[1], with a prevalence of physical activity insufficiency between 84.2% and 91.2% in Chilean children and adolescents[2]. Cardiorespiratory fitness is a component of physical fitness that involves the uptake, transport, and utilization of oxygen, and activates the heart, pulmonary and systemic circulation, and skeletal musculature during physical exercise[3-6]. Cardiorespiratory fitness is important during childhood because it is a predictor of cardiometabolic risk in adolescence[7], and its stimulation or development in childhood can be related to good health in adulthood[8,9].

Cardiorespiratory fitness can be assessed directly in the laboratory, but its high cost limits its use in epidemiology and the school context[10], although it can also be performed with field tests. One of these is the *Course-Navette* test, which is widely used in young people[10], and another is the Six-Minute Walk Test (SMWT), which is submaximal and is used to assess distance traveled and exercise capacity[11]. In addition, it is reported to be a good instrument to apply to elementary school children and even to children with different diseases[11].

Systematic reviews in children and adolescents propose reference values[12] and equations that allow predicting the distance walked in the SMWT[13,14]. In Chile, some studies propose prediction formulas for the meters walked in the SMWT in children from 6 to 14 years of age[15] and in adolescents of 16 years of age on average[16]. For more than 20 years, results of SMWT in healthy children from 6 to 14 years of age have been published[17], but none so far has developed equations that address cardiorespiratory fitness. In this context, it is of interest to generate an estimation model since this variable reflects the cardiorespiratory fitness of students. It is equally important because of the practical usefulness and the scope that this evaluation tool can have for physical activity and health professionals. The primary objective is to determine the performance in the SMWT and relate it to the aerobic power of the *Course-Navette* test, with demographic, anthropometric, and physical activity variables, and as a secondary objective, to verify its incidence in the prediction of $\dot{V}O_2max$ in second cycle primary education students of the Maule Region, Chile.

Patients and Method

Observational cross-sectional study. Male and female students from different schools of the second cycle of primary education in the Maule Region, Chile, all in urban areas, participated. The sample was purposive or non-probabilistic, totaling 456 children aged 11.9 ± 1.3 years (table 1). Formal and regular students from their schools were included, apparently healthy and without injuries in the musculoskeletal system such as contusions, sprains, "physical disability", fractures, etc., or any other type of physical impairment that would limit the development of the tests. Parents/guardians/responsible parties signed a consent form and informed assent from the students to participate in the study. The research was approved by the Scientific Ethics Committee of the *Universidad Católica del Maule* (Act No. 186 / 2 018). In addition, the study followed the guidelines of the Declaration of Helsinki.

In consecutive sessions, weight, height, and body mass index (BMI) were measured, then the SMWT was administered in 30-meter corridors[18] in which the distance traveled was counted, recovery heart rate (HR) was measured by individual carotid palpation, and subjective sensation of fatigue (RPE) was recorded[12]. After approximately 10 minutes, the *Course-Navette* test was applied where the last completed period was counted to calculate the $\dot{V}O_2max$[1,19], and the RPE was recorded with the EPInfant Scale[12,20]. Only the PAQ-C questionnaire[21] was applied preliminarily in a subgroup of students to determine the level of physical activity (PA).

The response or exposure variable was $\dot{V}O_2max$, and the independent or exploratory variables were the demographic variables of age, basic anthropometric variables of body weight, height, BMI, SMWT performance of distance traveled, and heart rate.

In the statistical analysis, mean values and standard deviation were calculated for continuous variables and percentages for categorical variables, the normality distribution of the data was also verified, and boys and girls were compared concerning basic anthropometry, cardiorespiratory fitness in the *Course-Navette* test and the SMWT between boys and girls with the Kruskal-Wallis test. In addition, the prevalence of gender (male, female) on the level of PA was evaluated with the Chi-square test. Partial correlations were performed between *Course-Navette's* $\dot{V}O_2$max and independent variables, and then linear regression models were performed having as dependent variable the *Course-Navette's* $\dot{V}O_2$max, and as independent variables the SMWT performance, basic anthropometric, and demographic variables. The validity of the models was verified with the Bland-Altman diagram including confidentiality ranges of ± 1.96. The analysis was performed with the R Commander® software version 4.2.2 (New Zealand) considering a statistical significance of $p < 0.05$.

Results

Table 1 shows that of the total participants (N = 59), there were no differences between males (n = 215) and females (n = 244) in demographic and basic anthropometric variables (age, weight, height, BMI), SMWT performance (distance covered, heart rate, perceived exertion), and *Course-Navette* test (period, speed, $\dot{V}O_2$max, perceived exertion). In addition, it is shown that most students in the subgroup examined had a moderate level of PA and that there was insufficient evidence to claim that the gender of the students (male or female) determined the level of PA (43 students were eliminated because of incomplete data).

Table 2 shows the partial correlations between $\dot{V}O_2$max and the independent variables. There were positive and significant correlations between $\dot{V}O_2$max, demographic variables (except age in females), and basic anthropometric variables. A negative relationship was also observed between $\dot{V}O_2$max and SMWT performance (except positive with distance) in the whole sample. Regarding the *Course-Navette* test performance, the association of $\dot{V}O_2$ max with RPE was inverse for the total participants.

In the sample of 459 students, the best predictive model included distance traveled (meters) at SMWT ($p = 0.02$), recovery HR (b-min^{-1}) 20 seconds post-walk, age in years, body weight in kg (all with $p < 0.001$), and height in meters ($p = 0.001$). There was no difference in estimated $\dot{V}O_2$max between males and females ($p = 0.1571$), then:

$$\dot{V}O_2\text{max (L·min}^{-1}) = -0.0902 + (-0.0464 \times \text{age}) + (0.0002 \times \text{distance}) + (-0.0019 \times \text{recovery HR}) + (0.5843 \times \text{height}) + (0.0353 \times \text{weight})$$

[Equation 1]

The statistics were: $r = 0.87$; $R^2 = 0.76$; $p < 0.001$ and estimation error = 0.25 L·min^{-1}.

The incidence of BMI in kg·m^{-2} on cardiorespiratory fitness was verified. This was statistically significant within the model as were the other variables ($p < 0.01$) but obtained slightly lower statistical values ($r = 0.75$; $R^2 = 0.57$; $p < 0.001$) and higher estimation error (0.34 L·min^{-1}), although there was no difference between males and females when predicting $\dot{V}O_2$max ($p = 0.4312$), then:

$$\dot{V}O_2\text{max (L·min}^{-1}) = -0.6152 + (0.0399 \times \text{age}) + (0.0933 \times \text{BMI}) + (0.0005 \times \text{distance}) + (-0.0022 \times \text{recovery HR})$$

[Equation 2]

For the subgroup of 172 participants, the level of PA was included in a linear model ($r = 0.89$; $R^2 = 0.79$; $p < 0.001$). In addition, distance, HR, body weight, age, and height presented statistical significance within the model ($p < 0.05$), except for the PA level itself ($p = 0.55$).

Also, the Bland-Altman plot (figure 1) showed that in equation [1], 27 pairs of the $\dot{V}O_2$max (5.9%) were outside the limits of agreement of the model, and the average bias was close to zero (0.049 L·min^{-1}) with confidence intervals (95%) of 0.017 - 0.064. For equation [2], only 22 pairs (4.8%) fell outside the limits and the bias was 0.046 L·min^{-1} (95%CI [-0.338; -0.275]).

Discussion

The main contribution of this research is that it has been possible to develop a model to predict $\dot{V}O_2$max in schoolchildren in a specific context in Chile, based on variables that are accessible to measure, noninvasive, and that the walking test does not require strenuous or maximal physical exertion. In addition, the level of PA is potentially predictive of $\dot{V}O_2$max.

Some research studies have addressed SMWT and determined the relationship with cardiopulmonary fitness in children and adolescents of different characteristics. In these, it has been reported that distance traveled was directly and significantly related to $\dot{V}O_2$max ($r = 0.72$) in healthy girls and boys of 10 years of age on average[22]. The same was true (0.31 to 0.69) in male and female adolescents with intellectual disability aged 16 years[23] and in adolescents aged 13 to 18 years with pulmonary hypertension in whom SMWT velocity was significantly related ($r = 0.59$) to $\dot{V}O_2$max[24]. In obese children, body weight, fat mass, and BMI were inversely and significantly associated with maximal oxygen consumption ($r = -0.26$ to -0.38), and fat-free

Table 1. Basic anthropometry, cardiorespiratory fitness and physical activity level

	Total (459)		Male (215)		Female (244)		
Variables	Mean	SD	Mean	SD	Mean	SD	p-value[a]
Age (years)	11.9	1.3	11.9	1.3	11.8	1.4	0.244
Weight (kg)	51.3	12.2	52.1	12.9	50.6	11.4	0.209
Height (m)	1.52	0.09	1.53	0.1	1.51	0.08	0.556
BMI ($kg{\cdot}m^{-2}$)	21.9	3.9	22	4	21.8	3.9	0.575
SMWT							
Distance (m)	656.9	93.3	650	100.4	663	86.4	0.211
HR ($b{\cdot}min^{-1}$)	113	30	111	28	115	31	0.353
HR (%)	54.2	14.2	53.4	13.6	55	14.8	0.377
RPE	5	2	5	2	5	2	0.632
Course Navette							
Period	3.1	1.5	3.1	1.7	3	1.4	0.734
Speed ($km{\cdot}h^{-1}$)	9.3	0.9	9.3	1	9.3	0.9	0.984
$\dot{V}O_2max$ ($ml{\cdot}kg{\cdot}min^{-1}$)	39.7	4.9	39.7	4.9	39.6	5	0.897
$\dot{V}O_2max$ ($L{\cdot}min^{-1}$)	2	0.5	2	0.5	1.9	0.4	0.235
RPE	8	2	8	1	8	2	0.127
PAQ-C (PA level)	n (172)	%	n (97)	%	n (75)	%	0.29
Very low	0	0	0	0	0	0	
Low	17	9.9	10	10.3	7	9.3	
Moderate	107	62.2	55	56.7	52	69.3	
High	44	25.6	30	30.9	14	18.7	
Intense	4	2.3	2	2.1	2	2.7	

[a]differences between male and female; HR (%): percentage of heart rate; HR: post-walk recovery heart rate; PA: physical activity; PAQ-C: Physical Activity Questionnaire for Children; RPE: rate of perceived exertion with the Epinfant Scale; SD: standard deviation; SMWT: Six-Minute Walk Test; $\dot{V}O_2$: maximal oxygen consumption.

Table 2. Correlation between Course Navette VO_2max and independent variables

	$\dot{V}O_2max$ ($L{\cdot}min^{-1}$)		
Variables	Total (459)	Male (215)	Female (244)
Age (years)	0.22**	0.34**	0.09
Weight (kg)	0.85**	0.87**	0.82**
Height (m)	0.59**	0.69**	0.46**
BMI (kg·m-2)	0.72**	0.69**	0.75**
SMWT			
Distance (m)	0.1*	0.05	0.14*
HR (b·min-1)	-0.11*	-0.12	-0.05
HR (%)	-0.1*	-0.1	-0.04
RPE	-0.23**	-0.33**	-0.14*
Course Navette			
Period	0.39**	0.41**	0.37**
Speed (km·h-1)	0.41**	0.44**	0.41**
RPE	-0.17**	-0.25**	-0.09

HR (%): percentage of heart rate; HR: post-walk recovery heart rate; RPE: rate of perceived exertion with the Epinfant Scale; SMWT: Six-Minute Walk Test. *< 0.05; **< 0.001

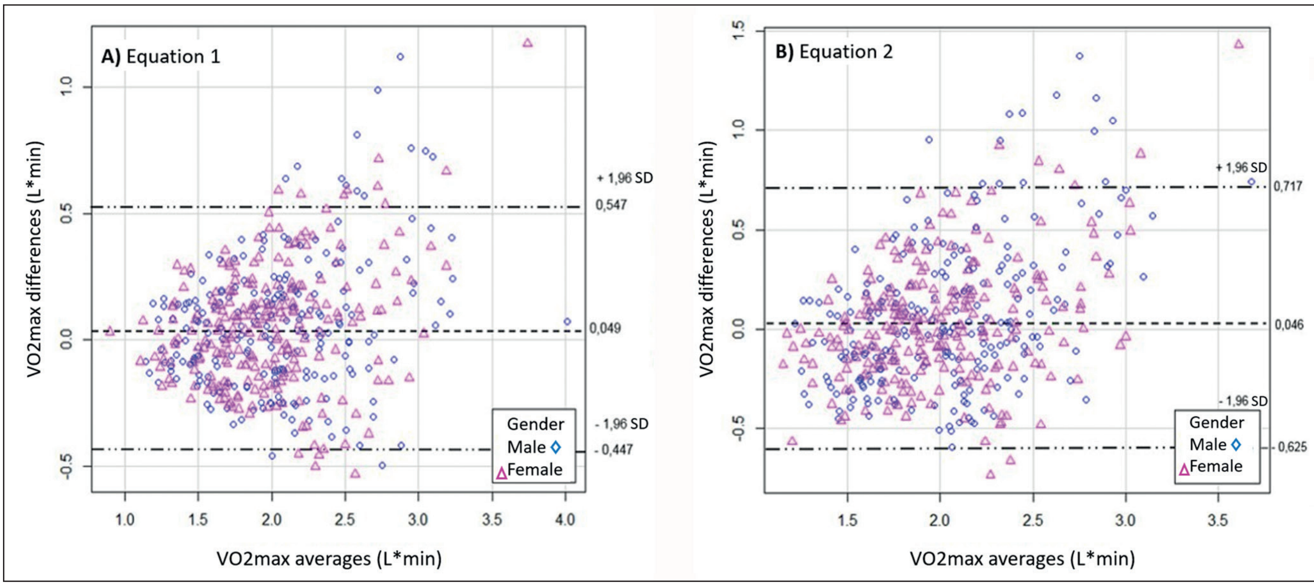

Figure 1. Bland-Altman diagram. Degrees of agreement for VO_2max between the cardiorespiratory test (Course Navette) and the predictive equations. Y-axis: Differences in $\dot{V}O_2$ (L·min-1). X-axis: Averages of $\dot{V}O_2$ (L·min-1).

mass and distance in SMWT were also directly and significantly associated (r = 0.22 to 0.24)[25]. We highlight these characteristics of the participants as the measurement of cardiorespiratory fitness and SMWT ranges from the clinical setting to apparently healthy children performing in schools, as there are variables that are commonly measured which are potentially predictors of $\dot{V}O_2$max, as described in our study.

Regarding research that has developed models to estimate $\dot{V}O_2$max in children, one study has incorporated distance covered in SMWT and BMI in 12-year-old children on average[26] in which, in addition age ($r = 0.11$; $p < 0.05$), body weight ($r = -0.36$; $p < 0.001$), and HR ($r = -0.12$; $p < 0.05$) at the end of the walking test, were significantly related to $\dot{V}O_2$max obtained in a stress test. Another research has worked with obese children with an average age of 13 years where they have performed the prediction of $\dot{V}O_2$max from the distance covered in the SMWT and BMI[25]. Some of the variables that these studies have used coincide with those that we have used with Chilean schoolchildren, such as BMI, and others that did show a relationship with $\dot{V}O_2$max we included in the predictive models (age, weight, and HR).

We should point out that an important variable is the level of PA that we incorporated to relate to $\dot{V}O_2$max. On this point, a significant relationship of $\dot{V}O_2$max with PA (in steps/week) has been found[26] and, in another study[27], they included PA by self-report in a predictive equation for distance in SMWT in girls. This evidence indicates that it is plausible to include PA performed by schoolchildren as an explanatory variable for cardiopulmonary fitness.

The implication of this study in the clinical aspect is justified by the relevance of maximal oxygen consumption being associated with cardiometabolic diseases, basic anthropometry, and lifestyles, treated in the public health system of the population[28-32]. So much so, that oxygen consumption has been cataloged as an input variable in the clinical evaluation[33,34], that is, in the diagnostic evaluation such as the measurement of vital signs and other basic parameters. Besides, the application of the SMWT is transferable and becomes relevant in the clinical setting since it has been used in different populations, whether in adults with lung[35] and heart diseases[36], vascular accidents[37], and, regarding the age group, in children and adolescents with various pathologies[38-40].

Thus, the impact of $\dot{V}O_2$max in the research and clinical sphere may have a preventive nature in the development of cardiometabolic diseases and, at the same time, as a complement to the treatment of these pathologies, considering the general repercussions on cardiorespiratory fitness that we could find in children and adolescents in this post-pandemic stage, and particularly in those who were affected by the pediatric inflammatory multisystem syndrome associated with COVID-19[41]. The latter is very relevant since evidence has shown that cardiorespiratory fitness had a significant decrease between September

2019 and September 2020 in school children aged 7 to 10 years, and then increased slightly or remained unchanged until June 2021[42], therefore, it is pertinent to have accessible means to assess $\dot{V}O_2$max and can provide methods for its development in the child population.

A limitation of this study is that $\dot{V}O_2$max was determined with an indirect method such as the *Course-Navette* test and not a laboratory criterion test. However, there is considerable evidence reporting the reliability and validity of that test for estimating $\dot{V}O_2$max in children and adolescents in Chile, Latin America, and worldwide[1,4,10]. On the other hand, in the subgroup of students, the level of PA was measured through a questionnaire (PAQ-C) which could over- or underestimate the perception[43] of the students' performance of PA. Another limitation is the fact that it is not possible to assume a cause-effect relationship between the variables studied since it was a cross-sectional study, for example, despite demonstrating an incidence of BMI on cardiorespiratory fitness with this methodological design, it is not possible to accept such a causal association. On the other hand, one of its strengths was that it was one of the first studies on this subject in Chile and that it had a large number of participants.

The projections of the research are to evaluate $\dot{V}O_2$max with a direct method, a gold standard as a criterion, and thus access more variables associated with $\dot{V}O_2$max (ventilatory thresholds and gas exchange), in the students who are the subject of this research. In addition, and jointly, to perform a longitudinal study to evaluate the consistency and reproducibility of the associations between oxygen consumption and the covariates investigated in this study, plus the association with other cardiometabolic variables, basic anthropometry, and lifestyles.

Finally, as the variables of distance covered in SMWT, recovery HR, age, height, body weight, and BMI are predictors of $\dot{V}O_2$max, the equations developed in this study could be applied in populations with similar characteristics to have an approximation of cardiorespiratory fitness, considering the morpho-functional, geographic, and environmental differences, among others, of each specific context for the interpretation of the results.

Conclusions

Cardiorespiratory fitness determined with indirect method and expressed as $\dot{V}O_2$max is related to SMWT performance specifically with distance and post-walk HR, also with basic anthropometry (weight and BMI), age, and with lifestyles such as PA level in the schoolchildren who participated in the study.

Ethical Responsibilities

Human Beings and animals protection: Disclosure the authors state that the procedures were followed according to the Declaration of Helsinki and the World Medical Association regarding human experimentation developed for the medical community.

Data confidentiality: The authors state that they have followed the protocols of their Center and Local regulations on the publication of patient data.

Rights to privacy and informed consent: The authors have obtained the informed consent of the patients and/or subjects referred to in the article. This document is in the possession of the correspondence author.

Conflicts of Interest

Authors declare no conflict of interest regarding the present study.

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