Criterion Related Validity of 1/2 Mile Run-walk Test for Estimating VO_{2peak} in Children Aged 6–17 Years

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Key words
- cardiorespiratory fitness
- 1/2 mile run/walk
- validity
- children
- Bland-Altman

Abstract

We assessed the criterion related validity of 1/2 mile run/walk (1/2MRW) test for estimating VO_{2peak} in children aged 6–17 years. The criterion related validity of the Fernhall's equation in a sub-group of children aged 10–17 years was also examined. A total of 86 children completed a maximal graded treadmill test and the 1/2MRW test. The cohort was randomly divided into either validation (n = 47) or a cross-validation (n = 39) group. A regression equation was computed and assessed through several error measures, and the Bland and Altman method. There was no systematic bias in the validation group nor in the cross-validation group ($P > 0.1$). The root mean sum of squared errors (RMSE), and the percentage error were 6.5 ml/kg/min, and 13.9 %, respectively. These figures were very similar in the cross-validation group. The new equation had a lower RMSE and percentage error than the Fernhall's Equation (6.2 vs. 19.7 ml/kg/min, and 16 % vs. 50.4 %, respectively, $P < 0.001$). The Fernhall's equation showed a significant underestimation of VO_{2peak} (18.1 ml/kg/min, $P < 0.001$). In conclusion, the new regression equation is valid for estimating VO_{2peak} from the 1/2MRW time, sex, and body mass index in healthy children aged 6–17 years, and is more accurate than Fernhall's equation in the sample studied.

Introduction

There is increasing evidence indicating that cardiorespiratory fitness is an important health marker in children and adolescents [6,25]. Maximal (or peak) oxygen consumption (VO_{2peak}) is acknowledged as the best physiological measure of cardiorespiratory fitness [32]. Laboratory tests provide an accurate and reliable measurement of VO_{2peak}, yet have well-known limitations such as the necessity for trained laboratory personnel, expensive equipment and time constraints. Therefore, laboratory-based tests are not feasible when a large number of subjects need to be measured in a short period of time, which is the case in the school setting. To deal with these problems, a number of field tests have been developed to estimate cardiorespiratory fitness. Running-walking based field tests are by far the most popular type of tests to estimate cardiorespiratory fitness in both young people and in adults [15,22]. The appropriate length of the field-based run-walk test in young people to estimate VO_{2peak} is not clear. It has been suggested that the test should be at least 600 yards (~550 m) long [8,11], whereas others have recommended that under ideal circumstances, run-walk tests should have a distance of at least one mile (1 609 m) [11,13]. Several fitness test batteries have included the 1/2 mile run-walk (1/2MRW) test as a suitable test to assess cardiorespiratory fitness in young people [1,10,33,35]. This test consists of completing 1/2 mile as fast as possible. The 1/2MRWT may reduce the influence that important variables have in the running performance in early ages, such as psychological aspects (e.g. willingness to accept the strenuous effort, motivation and monotony), and pacing achieved [7,14,20,31]. In addition, it is likely that the influence of these variables on the performance increases when the tests is longer mainly due to the difficulty to keep the pace, as well as the motivation. Fernhall et al. [12] examined the criterion related validity of the 1/2MRW test in children aged 10–17 years with mental retardation. They developed a regression equation to estimate VO_{2peak} from the 1/2MRW time and body mass index (BMI). To the best of our knowledge, this is the only attempt made to develop an equation to estimate VO_{2peak} from the 1/2MRW performance.

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Therefore, whether Fernhall's equation can be applied in healthy children and adolescents is not known. Whether the 1/2MRW test is a valid test to estimate VO_{2peak} in healthy children and adolescents also remains to be elucidated.
The objective of the present study was to assess the criterion related validity of the 1/2MRW test for estimating VO_{2peak} in healthy children aged 6–17 years. To address this objective, we developed and cross-validated a regression equation in healthy children aged 6–17 years. Furthermore, we examined the criterion related validity of the Fernhall's equation in a sub-group of children aged 10–17 years.

Methods

Subjects

A total of 88 (42 girls and 46 boys) healthy white children and adolescents aged 6–17.9 years volunteered to participate in the study. All the children were of the same Caucasian (Spanish) descent for ≥3 generations. A comprehensive verbal description of the nature and purpose of the study was given to the children, adolescents, their parents and teachers. This information was also sent to parents or children supervisors by regular mail, and written consents from parents, children and adolescents were requested and obtained. The criteria for inclusion were: no personal history of cardiovascular or metabolic disease, free of disease, any muscular or skeletal injuries, medication at the time of the study and pregnancy. The study was approved by the Review Committee for Research Involving Human Subjects at the University of Cádiz, Spain.

Procedures

All participants performed the 1/2MRW test and a maximal graded exercise test (GXT) on a motor driven treadmill in random order within a 2-week period. Participants were asked to abstain from strenuous exercises 48 h prior to the test. The cohort was randomly divided into either validation (n = 47) or a cross-validation (n = 39) group. The analysis of variance (ANOVA) revealed no significant difference between the two groups in terms of age, weight, height, BMI, and 1/2MRW time.

1/2 mile run-walk test

Participants were instructed and encouraged to complete the distance of 1/2 mile as fast as possible. Walking was permitted if the participant could not keep running. The tests were performed on a 200 m track in the schools playground field. The time of completion was recorded to the nearest second. All the tests were conducted by the same investigators and at the same time for each subject (between 10:00 a.m. to 1:30 p.m.).

Maximal Treadmill GTX

The same participants also performed a graded maximal treadmill test (Eric Jaeger, GmbH & Co, Wurzburg, Germany). The test started with a 3-min warm-up at 4 km/h, at 3 % grade in children aged 6–10 years, and at 6 km/h in children aged 11 years or older. The grade was maintained at 3 % throughout the test. The speed was increased 1 km/h every minute until volitional fatigue. The test was finished when the participant was unable to continue despite verbal encouragement.
Heart rate was recorded every 5 s throughout the test using a JECg 12 Channel electromyography (Eric Jaeger, GmbH & Co, Wurzburg, Germany) which in turn was averaged over a 15 s period. Oxygen consumption was measured via open circuit spirometry using an automated gas analyser (Oxycon Delta Version 4.3, Eric Jaeger, GmbH & Co, Wurzburg, Germany) previously calibrated with standard gases. During each test, a gel seal was used to help prevent air leaks from the paediatric face masks. The highest VO_2 recorded during the test was accepted as VO_{2peak}, and it was confirmed when: 1) maximal heart rate was no more than 15 beats per minute below age-predicted maximal heart rate (220-age), and/or 2) respiratory exchange ratio was equal or greater than 1.1.
One week prior to the tests, all the participants received comprehensive instructions of the test, after which a familiarization session took place. A total of two male adolescents discontinued the treadmill test because of discomfort or distress, which probably yielded inaccurate VO_{2peak} results. Therefore, the final sample was confined to 86 (42 girls and 44 boys) children with reliable measures of VO_{2peak}.

Body mass index

Height and weight were measured while wearing shorts and T-shirts, and barefoot. Height was assessed to the nearest 0.1 cm using a stadiometer (Holtain Ltd, Crymmych, Pembs, United Kingdom). Weight was measured to the nearest 0.1 kg using a Seca scale. Instruments were calibrated to ensure the acceptable accuracy. BMI was calculated as weight/height squared (kg/m^2).

Statistical analyses

The data are presented as means ± SD. Sex differences were analyzed by one-way ANOVA in the validation and cross-validation group separately. Bivariate correlations were used to examine the relationship between measured VO_{2peak} and 1/2MRW time, and between measured and estimated VO_{2peak}. A stepwise multiple regression analysis was conducted to build the equation to estimate VO_{2peak} in children and adolescents aged 6–17 years. Age, sex, BMI, and 1/2MRW time were included in the model. Additional analyses were performed including height and weight instead of BMI.
The new developed equation to estimate VO_{2peak} was assessed through an error measure. Suppose that N cases are available to evaluate the model, where y is the actual output (measured VO_{2peak}) and $\hat{y}$ is the output computed by the equation (estimated VO_{2peak}). The sum of squared errors (SSE) was calculated as:

$$SSE = \sum_{i=1}^{N} (y_i - \hat{y}_i)^2$$

An easier way of understanding the expression of the error is to use the percentage error. To calculate the percentage error we calculated first the mean sum of squared errors (MSE):

$$MSE = \frac{1}{N} \sum_{i=1}^{N} (y_i - \hat{y}_i)^2$$

Where N is the number of cases.
MSE is then converted into domain units by taking the root square and yielding the root mean sum of squared errors (RMSE):

$$RMSE = \sqrt{MSE}$$

The percentage error is calculated as:

$$\%Error = \frac{RMSE}{domain\ width} \times 100$$

Table 1 Mean and (SD) of the study population.

	All		Girls		Boys	
validation group, n	47		25		22	
age, years	11.3	(3.4)	11.3	(3.5)	11.3	(3.3)
weight, kg	43.3	(15)	40.3	(11.9)	46.7	(17.4)
height, cm	150	(18.8)	146.9	(17.1)	153.5	(20.4)
BMI, kg/m^2	18.5	(2.7)	18.2	(2.3)	19	(3)
measured VO_{2peak}, ml/kg/min	57.4	(8.8)	53.6	(7)*	61.7	(8.7)
maximal speed T, km/hr	14.1	(2.4)	13.6	(1.9)	14.7	(2.4)
1/2MRW time, min	4.2	(0.8)	4.5	(0.7)*	3.8	(0.7)
maximal speed 1/2MRW, km/hr	12	(2.4)	11.4	(1.6)	13	(2.7)
cross-validation group, n	39		17		22	
age, years	10.8	(3.2)	10.9	(3.1)	10.7	(3.5)
weight, kg	42.5	(14.4)	42.3	(12.5)	42.8	(15.9)
height, cm	148.3	(19)	149	(15.9)	147.7	(21.5)
BMI, kg/m^2	18.8	(2.6)	18.7	(2.9)	18.8	(2.4)
measured VO_{2peak}, ml/kg/min	57.1	(8.6)	53.7	(6.4)*	59.7	(9.4)
maximal speed T, km/hr	13.6	(2.1)	13.3	(1.8)	13.8	(2.3)
1/2MRW time, min	4.1	(0.7)	4.3	(0.6)*	3.9	(0.8)
maximal speed 1/2MRW, km/hr	12.2	(2.3)	11.5	(1.8)	12.9	(2.5)

BMI indicates body mass index; 1/2MRW, 1/2 mile run/walk; T, treadmill
*$P<0.05$ for sex differences

We also calculated the standard error of estimate (SEE) as follows:

$$SEE = SD_y \sqrt{(1 - R^2_{y\hat{y}})}$$

where SD is the standard deviation of the estimated VO_{2peak}, and R^2 is the correlation between the measured VO_{2peak} and the estimated VO_{2peak}.

ANOVA for repeated measures was used to examine the SSE difference between the model and the validation sample, as well as between the new developed equation and the Fernhall's equation. Since Fernhall's equation was developed with children and adolescents aged 10–17 years, the analyses using that equation are restricted to those participants aged 10–17 years. The mean difference, 95% confidence intervals of the difference, and the 95% limits of agreement (mean difference ± 1.96 SD of the differences) were calculated. The difference between the measured VO_{2peak} and the estimated VO_{2peak} were calculated by means of ANOVA for repeated measures. The agreement between the measured VO_{2peak} and the estimated VO_{2peak} was assessed according to the Bland and Altman method [4,5]. The association between the difference and the magnitude of the measurement (i.e. heteroscedasticity) was examined by regression analysis, entering the difference between the measured and estimated VO_{2peak} as dependent variable and the averaged value [(measured + estimated)/2] as independent variable.

Results

Descriptive characteristics for the validation and cross-validation group by sex are displayed in **Table 1**. Boys had significantly higher levels of measured VO_{2peak} and spent less time to complete the 1/2MRW test than girls, in both the validation and cross-validation groups. The correlation coefficient between measured VO_{2peak} and 1/2MRW time was −0.552 ($P<0.001$) for the validation group, and −0.532 ($P<0.001$) for the cross-validation group. Despite verbal encouragement during the 1/2MRW test, maximal speed in the 1/2MRW was significantly lower than that achieved in the treadmill test ($P<0.05$). Overall, children run the 1/2MRW test at ~87% of the maximal aerobic capacity measured on the treadmill.

Table 2 Stepwise regression model estimating VO_{2peak} from the 1/2 mile run/walk time (in min), sex, and body mass index (kg/m^2).

Variable	Value	95% CI	P=
intercept	93.9	71.78/115.93	<0.001
sex	5.4	0.93/9.75	0.019
BMI	−0.8	−1.61/−0.02	0.044
1/2MRW Time	−5.7	−8.69/−2.71	<0.001
R		0.66	
R^2		0.44	

BMI indicates body mass index; 1/2MRW, 1/2 mile run/walk
Regression equation: Girls: −5.7 (1/2MRW, in min) − 0.8 (BMI, kg/m^2) + 93.9
Boys: −5.7 (1/2MRW, in min) − 0.8 (BMI, kg/m^2) + 99.3

Regression equation

The stepwise regression analysis showed that only 1/2MRW time, sex, and BMI were significantly associated with VO_{2peak} (**Table 2**).

The regression equation was:

$VO_{2peak} = -5.7$ (1/2MRW, in min) + 5.4 (sex, girls = 0, boys = 1) − 0.8 (BMI, kg/m^2) + 93.9.

The equation can be presented as follow:

Girls: −5.7 (1/2MRW, in min) − 0.8 (BMI, kg/m^2) + 93.9.

Boys: −5.7 (1/2MRW, in min) − 0.8 (BMI, kg/m^2) + 99.3.

Age was not significantly associated with VO_{2peak} ($P>0.1$). Weight and height did not significantly contribute to the model when entered separately instead of BMI (both $P>0.1$). The correlation coefficient between measured VO_{2peak} and estimated VO_{2peak} from the regression equation was −0.659 ($P<0.001$) in the validation group, and −0.589 ($P<0.001$) in the cross-validation group.

The error assessment of the estimated VO_{2peak} from the regression equation in the validation and cross-validation group is shown in **Table 3**. The SSE was not significantly different in the validation compared to the cross-validation group.

The agreement between the measured VO_{2peak} and the estimated VO_{2peak} from the regression equation in the validation and cross-validation group is depicted in **Fig. 1**. There was no systematic bias. The mean difference was −0.4 ml/kg/min (P > 0.1), and −1.7 ml/kg/min P > 0.1) in the validation and cross-validation group, respectively. There was no association of the measured and estimated VO_{2peak} difference with the measured and estimated VO_{2peak} mean in either the validation or cross-validation groups (both P > 0.1).

Validity of Fernhall's and new equation in children aged 10–17 years

The correlation coefficient between measured VO_{2peak} and estimated VO_{2peak} from the Fernhall's equation and the regression equation was 0.620, and 0.719, respectively (both P < 0.001).

The error assessment of the estimated VO_{2peak} from the Fernhall's and the regression equation is shown in **Table 4**. The SSE was significantly higher in the Fernhall's equation compared with that obtained with the regression equation (21295 vs. 2142.5, respectively, P < 0.001).

The agreement between the measured VO_{2peak} and the estimated VO_{2peak} from the Fernhall's equation is depicted in **Fig. 2**. There systematic bias was 18.1 ml/kg/min (P < 0.001). There was a significant positive association of the measured and estimated VO_{2peak} difference with the measured and estimated VO_{2peak} mean (P < 0.05).

Fig. 2 also shows the Bland-Altman plot for the measured VO_{2peak} and estimated VO_{2peak} from the regression equation in children and adolescents aged 10–17 years. There was no systematic bias (−0.6 ml/kg/min P > 0.1). There was not an association of the measured and estimated VO_{2peak} difference with the measured and estimated VO_{2peak} mean (P > 0.1).

Table 3 Error assessment of the estimated VO_{2peak} from the new regression equation in the validation and cross-validation sample.

	Validation (n = 47)	Cross-validation (n = 39)
SSE (ml/kg/min)^2	2013.1	1984.9
MSE (ml/kg/min)^2	42.8	50.9
RMSE (ml/kg/min)	6.5	7.1
error (%)	13.9	18.2
SEE (ml/kg/min)	4.4	4.7
mean difference/95 % CI (ml/kg/min)	−0.4/1.127	−1.7/1.119

SSE indicates sum of squared errors; MSE, mean of squared errors; RMSE, root mean squared errors; SEE, standard error of estimate; CI, confidence interval
Mean difference: measured VO_{2peak} minus estimated VO_{2peak}
Regression equation: Girls: −5.7 (1/2MRW, in min) − 0.8 (BMI, kg/m^2) + 93.9
Boys: −5.7 (1/2MRW, in min) − 0.8 (BMI, kg/m^2) + 99.3

Discussion

Regression equation

In the present study, a new regression equation to estimate VO_{2peak} from the 1/2MRW time, sex, and BMI in healthy children and adolescents aged 6–17 years has been developed and cross-validated. We did not observe a systematic bias in the validation group nor in the cross-validation group, nor an association between the difference and the magnitude of the measurement

Table 4 Error assessment of the estimated VO_{2peak} with the Fernhall's equation and with the new regression equation in children and adolescents aged 10–17 years (n = 55).

	Fernhall	Regression equation
SSE (ml/kg/min)^2	21 295	2 142.5*
MSE (ml/kg/min)^2	387.2	39*
RMSE (ml/kg/min)	19.7	6.2*
error (%)	50.4	16*
SEE (ml/kg/min)	7.1	4.3
mean difference/95 % CI (ml/kg/min)	18.1/2.986‡	−0.6/0.513

SSE indicates sum of squared errors; MSE, mean of squared errors; RMSE, root mean squared errors; SEE, standard error of estimate; CI, confidence interval
Mean difference: measured VO_{2peak} minus estimated VO_{2peak}
*P < 0.001 for Fernhall's equation vs. new equation
‡P < 0.001 for measured VO_{2peak} – estimated VO_{2peak}
Fernhall's equation: VO_{2peak} = −2.49 (1/2 mile time, in min) − 0.52 (body mass index, kg/m^2) + 59.9
Regression equation: Girls: −5.7 (1/2MRW, in min) − 0.8 (BMI, kg/m^2) + 93.9
Boys: −5.7 (1/2MRW, in min) − 0.8 (BMI, kg/m^2) + 99.3

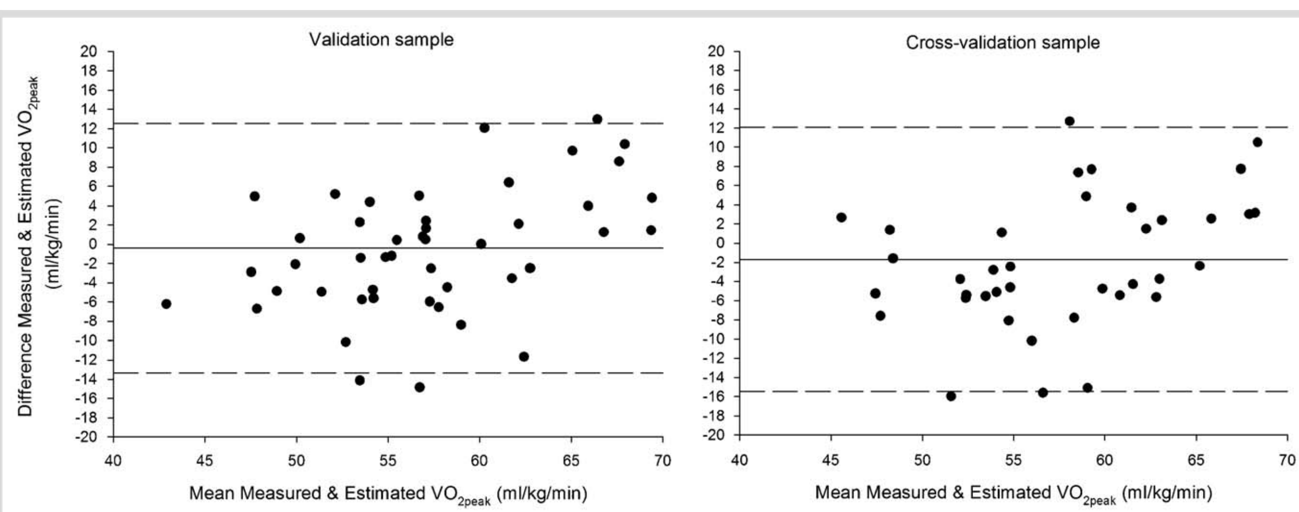

Fig. 1 Bland-Altman plot for the measured VO_{2peak} and estimated VO_{2peak} in the validation and cross-validation sample in children and adolescents aged 6–17 years. Solid line represents the mean difference (bias) between measured and estimated VO_{2peak}. Upper and lower dashed lines represent the 95 % limits of agreement (mean difference ± 1.96 SD of the difference).

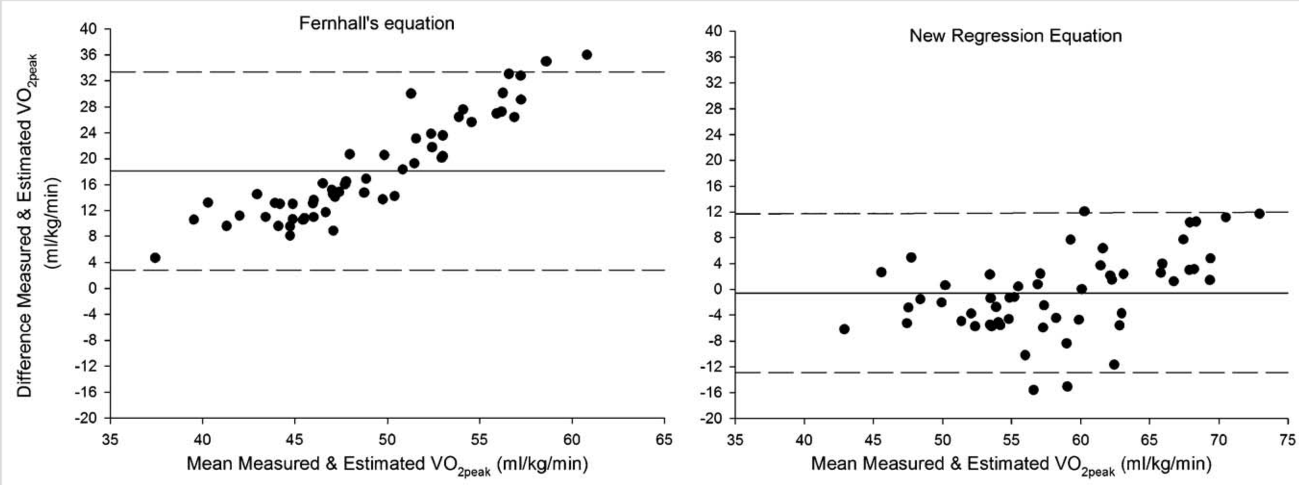

Fig. 2 Bland-Altman plot for the measured VO_{2peak} and estimated VO_{2peak} from the Fernhall's equation and from the new regression equation in children and adolescents aged 10–17 years. Solid line represents the mean difference (bias) between measured and estimated VO_{2peak}. Upper and lower dashed lines represent the 95 % limits of agreement (mean difference ± 1.96 SD of the difference).

(i.e. heteroscedasticity). The correlation coefficient between the measured VO_{2peak} and the 1/2MRW time was −0.552 ($P<0.001$) for the validation group, and −0.532 ($P<0.001$) for the cross-validation group, which is in accordance with the data reported by Fernhall et al. ($r=-0.60$, $P<0.01$) [12]. Moreover, the 1/2MRW time accounted for 19.5 % of the VO_{2peak} variance, suggesting that other variables might also have an influence in the levels of VO_{2peak} in young individuals. The correlation coefficient went up to 0.66 when sex and BMI were included into the model, and the variance explained by the full model was 44 %. Other variables such as genetics, maturation, running economy and behavioural factors may also play a key role in the 1/2MRW performance.

Body size, as measured by BMI, was significantly associated with VO_{2peak} ($\beta=-0.80$, $P=0.044$). Likewise, Fernhall et al. [12] reported a negative correlation between BMI and VO_{2peak} ($\beta=-0.50$, $P<0.01$). It is important to control the effect of changes in body size in order to understand the relative contributions of other factors on VO_{2peak}, such as sex, maturation, habitual physical activity, and functional cardiorespiratory improvements. We observed that BMI was a better predictor than weight and height separately, which agrees with the data shown by Cureton et al. [9]. Weight and height did not significantly contribute in the estimation of VO_{2peak}.

The stepwise regression analyses showed that age was not significantly associated with VO_{2peak} ($\beta=-0.30$, $P=0.524$). Compared to adults, young individuals generally have lower VO_{2peak} when expressed in absolute terms (i.e. ml/min). When related to body weight (ml/min/kg), however, VO_{2peak} is relatively stable for boys and decreases only slightly for girls during growth [16, 24]. It has been suggested that rather than using the chronological age as a measure for this variable, sexual maturation (i.e. biological age) might be a more accurate marker of the physiological status of the person in this particular period of life [27]. However, findings from cross-sectional studies examining the influence of sexual maturation on VO_{2peak} have shown that sexual maturation accounts for only a small proportion of the variance in the measured VO_{2peak} value [21]. Sexual maturation was not included in the equation due to the suspected inaccuracy in self-reporting Tanner stage in some circumstances, and the need for a paediatrician or trained physician to make an objective measurement, which in most settings, such as schools, is not feasible.

Validity of Fernhall's and new regression equation in children aged 10–17 years

Fernhall et al. [12] developed a regression equation to estimate VO_{2peak} from the 1/2MRW time and BMI in children aged 10–17 years with mental retardation. To make the equations comparable, we also examined the criterion related validity of Fernhall's equation and of our regression equation in a sub-group of children and adolescents aged 10–17 years. The regression equation developed in the present study is more accurate than Fernhall's equation. Fernhall's equation showed a significant underestimation of VO_{2peak} levels (18.1 ml/kg/min), whereas our equation did not overestimate the levels of VO_{2peak} (−0.6 ml/kg/min). Moreover, the new regression equation had a lower percentage error and SEE than Fernhall's Equation (16 % vs. 50.4 %, and 4.3 vs. 7.1 ml/kg/min, respectively). Differences in the results obtained between Fernhall's equation and the new regression equation may be partly due to the inclusion of a new variable in the model, which is sex. This variable was not included in Fernhall's equation, yet it is known to influence the level of VO_{2peak}. Moreover, Fernhall's equation presented heterocedascity, that is, that the error of the estimation increases when the levels of VO_{2peak} increases.

Fernhall et al. [12] speculated that behavioural factors such as effort and pacing, as well as running economy could explain the poor accuracy of the 1/2MRW test to predict VO_{2peak} in children with mental retardation. They suggested that the accuracy to predict VO_{2peak} from the 1/2MRW test in this special population might not be as good as in their peers without mental retardation. However, the findings in this study showed that Fernhall's equation has the same accuracy for children and adolescents without mental retardation.

The reliability of the 1/2MRW test in children and adolescents has not been thoroughly examined, and has been mainly confined to correlation analysis. To our knowledge, only one study has examined the reliability of the 1/2MRW test in young people [28]. Rikli et al. [28] reported correlation coefficients ranging from 0.74 to 0.79 in boys, and from 0.47 to 0.77 in girls aged 5–9 years, and showed that the 1/2MRW test is more reliable than the 1 mile run-walk test in children aged 5–7 years. Further reliability studies using more advanced and appropriate statistical analyses are needed.

Other tests have been used to assess cardiorespiratory fitness in children and adolescents. One of the most widely used field tests for estimating cardiorespiratory fitness in youth is the 20 m shuttle run test, also called the "Course Navette" test [17,34]. The 20 m shuttle run test consists of 1-min stages of continuous incremental speed running. The participants run between two lines 20 m apart, while keeping the pace with audio signals emitted from a pre-recorded CD. The initial speed is 8.5 km/h, and increases by 0.5 km/h per minute. The test ends when the participant fails to reach the end lines concurrent with the audio signals on two consecutive occasions. The 20 m shuttle run test has shown to be a test with an acceptable validity [2,18,19,29] and reliability [3,18,23,26]. It is also a feasible fitness test, especially in school settings, since it is easy to administer and time efficient, a relatively large number of subjects can be tested simultaneously, and involves minimal equipment and low cost [30].

In summary, we have developed and cross-validated a regression equation for predicting VO_{2peak} from the 1/2MRW time, sex, and BMI in healthy children and adolescents aged 6–17 years. We did not observe a significant difference between measured and estimated VO_{2peak}, nor heteroscedascity. An acceptable error was also shown. The new regression equation is more accurate than the Fernhall's equation in the sample of children and adolescents studied.

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