Nutrición Hospitalaria

Nutr Hosp. 2011;26(3):572-578
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Original

Percentile values for aerobic performance running/walking field tests in children aged 6 to 17 years; influence of weight status

J. Castro-Piñero[1,2], F. B. Ortega[2,3], X. D. Keating[4], J. L. González-Montesinos[1], M. Sjöstrom[2] and J. R. Ruiz[2,5]

[1]Department of Physical Education. School of Education. University of Cadiz, Puerto Real 11519, Spain. [2]Unit for Preventive Nutrition. Department of Biosciences and Nutrition at NOVUM. Karolinska Institutet. Huddinge SE-141 57. Sweden. [3]Department of Physiology. School of Medicine. Granada 18012. Spain. [4]Department of Curriculum and Instruction. University of Texas at Austin. Austin. TX 787312. United States. [5]Department of Physical Education and Sport. School of Physical Activity and Sport Sciences. University of Granada. Granada. Spain.

Abstract

The aim of this study was to provide percentiles values for four different aerobic performance tests in 2752 (1,261 girls) Spanish children aged 6 to 17.9 years. Aerobic performance was assessed by the shuttle run test (20mSRT), 1-mile, 1/2-mile and 1/4-mile run/walk tests. Height and weight were measured, and body mass index was calculated. Boys had significantly better score than girls in the studied tests in all age groups, except in 1/4-mile test in 6-7 year old children. Underweight children had similar performance than their normalweight counterparts, and underweight boys had better performance than their obese counterparts. Overweight and obese children had lower performance than their normalweight counterparts. Having percentile values of the most used field tests to measure aerobic performance in youth may help to identify children and adolescents at risk for the major chronic diseases, as well as to evaluate the effects of alternative interventions.

(*Nutr Hosp.* 2011;26:572-578)

DOI:10.3305/nh.2011.26.3.4597

Key words: *Fitness. 20m shuttle run test. 1-mile. ½-mile. ¼-mile. Children.*

VALORES DE PERCENTILES DE LOS TESTS DE CAMPO DE CAPACIDAD AERÓBICA EN NIÑOS DE 6 A 17 AÑOS; INFLUENCIA DEL PESO CORPORAL

Resumen

El propósito de este estudio fue proporcionar los valores de percentiles para cuatro pruebas de rendimiento aeróbico en 2752 (1261 chicas) niños españoles con edades de 6 a 17,9 años. El rendimiento aeróbico se evalúo mediante la carrera durante 20 minutos (20mSRT), y las pruebas de correr / caminar 1 milla, ½ milla y ¼ de milla. Se midieron el peso y la talla y se calculó el índice de masa corporal. Los chicos tuvieron puntuaciones significativamente mejores que las chicas en las pruebas evaluadas y para todos los grupos de edad, excepto en la prueba de ¼ de milla en el grupo de 6-7 años. Los niños con peso bajo mostraron un rendimiento similar a sus homólogos con peso normal y los primeros tuvieron un rendimiento mejor que sus homólogos obesos. Los niños obesos y con sobrepeso tuvieron un menor rendimiento que sus homólogos con peso normal. El disponer de valores de percentiles para las pruebas empleadas más habitualmente para evaluar el rendimiento aeróbico en los jóvenes podría ayudar a identificar a niños y adolescentes en riesgo de enfermedades crónicas importantes así como a evaluar los efectos de intervenciones alternativas.

(*Nutr Hosp.* 2011;26:572-578)

DOI:10.3305/nh.2011.26.3.4597

Palabras clave: *Forma física. Prueba de carrera de 20 min. 1 milla. ½ milla. ¼ de milla. Niños.*

Correspondence: José Castro-Piñero.
Department of Physical Education.
School of Education. University of Cádiz.
11519 Puerto Real. Spain.
E-mail: jose.castro@uca.es

Recibido: 16-XI-2009.
Aceptado: 22-XI-2009.

Abbreviations

20mSRT: The 20m shuttle run test.
BMI: Body mass index.
CD: Compact Disk.
SD: Standard deviations.
L: Transformation.
M: Median.
S: Coefficient of variation.
SPSS: Statistical Package for Social Sciences.

Introduction

Cardiorespiratory fitness is a direct indicator of individual's physiological status and reflects the overall capacity of the cardiovascular and respiratory system.[1] There are a number of cross-sectional studies showing that children and adolescents with higher levels of cardiorespiratory fitness have also a more favourable cardiovascular profile compared with their unfit counterparts.[2] Likewise, findings from prospective cohort studies have suggested that a low cardiorespiratory fitness during childhood and adolescence is associated with later cardiovascular risk factors such as hyperlipidemia, hypertension and obesity.[2,3] There is evidence indicating that the level of cardiorespiratory fitness during childhood and adolescence is moderately associated with the level of fitness in adulthood.[4] Taken together, these findings support the existence of an association between cardiorespiratory fitness and health-related outcomes in young people, and highlight the importance to include cardiorespiratory fitness tests in monitoring systems from early ages.

Cardiorespiratory fitness can be objectively and accurately measured through laboratory tests, which seems to provide a valid and reliable measure of the outcome. However, laboratory tests present some disadvantages, as necessity of sophisticated instruments, qualified technicians, cost and time constraints. Therefore, the feasibility and cost efficiency have to be taken into consideration in field-based testing. In some circumstances, field tests may be a better option because the tests are generally easy to administer and time efficient, a large number of subjects can be tested simultaneously, are relatively safe, involve minimal equipment and low cost, and often are the only feasible methods. Among various field-based cardiorespiratory fitness tests, the 20m shuttle run test (20mSRT), 1-mile, +1/2-mile, and 1/4-mile run/walk tests are the most used in children and adolescents, and are included in the most important fitness test batteries for young people such as EUROFIT,[5] FITNESGRAM,[6] the Australian Fitness Education Award,[7] and the President´s Challenge: The Health Fitness Test.[8] Sex- and age-specific data for different cardiorespiratory fitness tests may help to identify the target population for primary prevention, as well as for health promotion policies.

Obesity is an important public health threat for the coming years. Therefore, to better understand how weight status influence cardiorespiratory fitness in children is also of public health interest.

The aim of this study was to provide percentile values for 20mSRT, 1-mile, 1/2-mile and 1/4-mile in a large sample of girls and boys aged 6 to 17.9 years, and to examine the influence of weight status on the fitness level across age groups.

Methods

Design and sample

A random sample of 2,752 (1261 girls and 1491 boys) healthy white children (6 to 17.9 years of age) was selected by a two-phase proportional-cluster sampling using as a reference the database of the Census of the province of Cádiz (Spain). In the first phase, the school was selected from the stratum. The different strata were selected according to the geographical localization, by age and sex. A total of 18 governmental schools agreed to participate in the study. In the second phase, classes from schools were randomly selected and used as the smallest sampling units. All the children of the selected classrooms were invited to participate in the study. The participation rate was higher than 95%.

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. The study was approved by the Review Committee for Research Involving Human Subjects at the University of Cádiz, Spain.

Body mass index assessment

Height and weight were measured with physical education clothing (shorts and T-shirts) and with 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. Body mass index (BMI) was calculated as weight/height squared (kg/m^2). Participants were categorized according to the BMI international cut-off values as underweight, normalweight, overweight and obese.[9,10]

20m shuttle run test

The test was performed as previously described by Léger et al.[11]. In brief, participants were required to run between two lines 20 m apart, while keeping the pace with audio signals emitted from a pre-recorded compact disk (CD). The initial speed was 8.5 km/h, which was increased by 0.5 km/h per minute (one minute equal one stage). The CD used was calibrated over one minute of duration. Participants were instructed to run in a straight line, to pivot on completing a shuttle, and to pace themselves in accordance with the audio signals. The participants were encouraged to keep running as long as possible throughout the course of the test. The test was finished when the participant failed to reach the end lines concurrent with the audio signals on two consecutive occasions. Otherwise, the test ended when the subject stopped because of fatigue. All measurements were carried out under standardized conditions on an indoor rubber floored gymnasium. The last stage completed was scored (precision of 0.5 steps).

1-mile, 1/2-mile and 1/4-mile run/walk tests

Participants were instructed and encouraged to complete the distance (i.e. 1-mile, 1/2-mile, or 1/4-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 play ground field. The time of completion was recorded to the nearest second.

All the participants received a comprehensive instruction of all the tests after which they also practiced the tests. They were instructed to abstain from strenuous exercises 48 hours prior to the test. The tests were randomly performed 7 to 10 days apart.

Statistical analysis

Participants were divided into five age groups: 6-7, 8-9, 10-11, 12-13, 14-15, 16-17 years. Age- and sex-specific means, and standard deviations (SD) were determined, unless otherwise indicated. Percentile values were calculated and percentile curves were fitted to the data using Cole's transformation, median, and coefficient of variation (LMS) method.[12] Briefly, this assumes that the data can be transformed to normality by a suitable power transformation (L), and the distribution is then summarized by the median (M) and coefficient of variation (S). The values of L, M and S are constrained to change smoothly with age, and the fitted values can be used to construct any required percentile curves. Sex and age groups differences were compared by two-way analysis of variance. Differences in aerobic performance tests among BMI categories (i.e., underweight, normalweight, overweight and obese) were compared by one-way analysis of covariance after adjusting for age. We adjusted multiple comparisons for mass significance as described by Holm.[13] All the residuals showed a satisfactory pattern. Nominal variables were analyzed by Chi-squared tests. All analyses were performed using the Statistical Package for Social Sciences (SPSS, version 15.0 for WINDOWS; SPSS Inc, Chicago). For all analyses, the significance level was set at 5%.

Results

The prevalence of underweight, normalweight, overweight and obese in girls was of 7%, 67%, 21%, and 5%, respectively, whereas in boys was 5%, 62%, 25%, and 8%, respectively.

Table I shows the means and SD for the four fitness tests by age group and sex. Boys had significantly better scores than girls in all four tests and in all age groups, except in 1/4-mile test in the 6-7 year old group.

Means and SD for the fitness tests by sex groups and weight status are presented in table II. Underweight children had similar performance than their normalweight counterparts, except in the 1/4-mile test, where underweight boys had lower performance than their normalweight counterparts. Underweight boys had higher performance than their obese counterparts in all the studied tests, and the former had also better performance than their overweight peers in the 20mSRT. Normalweight children had significantly better performance than their overweight and obese counterparts. Obese boys had significantly worse performance than their overweight counterparts, but not in girls.

Table I
Means and standard deviation for aerobic performance tests by sex and age

Fitness test	*Sex*	*n*	*6-7 yr*	*8-9 yr*	*10-11 yr*	*12-13 yr*	*14-15 yr*	*16-17 yr*
20m shuttle run (stages)	Girls	1173	2.3 ± 1.0**	2.9 ± 1.2***	3.4 ± 1.8***	4.3 ± 1.9***	4.2 ± 2.0***	3.9 ± 1.7***
	Boys	1424	2.6 ± 1.4	3.6 ± 1.8	4.1 ± 1.9	5.5 ± 2.2	6.7 ± 2.5	6.6 ± 2.5
1/4-mile run/walk (min)	Girls	1166	2.5 ± 0.4	2.5 ± 0.5***	2.4 ± 0.7**	2.2 ± 0.7***	2.1 ± 0.5***	2.2 ± 0.5***
	Boys	1443	2.4 ± 0.4	2.3 ± 0.5	2.3 ± 0.5	1.8 ± 0.4	1.7 ± 0.4	1.6 ± 0.4
1/2-mile run/walk (min)	Girls	1079	5.4 ± 0.7	5.6 ± 1.3***	5.3 ± 1.0***	4.9 ± 1.3***	4.9 ± 1.1***	4.9 ± 1.0***
	Boys	1321	5.2 ± 1.0	5.0 ± 1.0	4.8 ± 1.0	4.2 ± 0.8	3.9 ± 0.9	3.6 ± 0.8
1-mile run/walk (min)	Girls	1221	11.5 ± 2.0	12.0 ± 1.9***	11.5 ± 2.2***	11.1 ± 2.7***	11.0 ± 2.2***	10.9 ± 1.9***
	Boys	1120	11.0 ± 1.6	10.7 ± 2.1	10.5 ± 2.2	9.4 ± 2.0	8.8 ± 2.1	8.1 ± 1.5

**P < 0.01; ***P < 0.001 for comparison between sexes.

Table II
Means and standard deviation for aerobic performance tests by weight status and sex

	n	Underweight (A)	Normal weight (B)	Overweight (C)	Obese (D)	P for trend	Post hoc pairwise comparisons					
							A vs B	A vs C	A vs D	B vs C	B vs D	C vs D
Girls												
20m shuttle run (stages)	1075	3.8 ± 0.2	3.6 ± 0.1	2.9 ± 0.1	2.4 ± 0.2	< 0.001	NS	< 0.001	< 0.001	< 0.001	< 0.001	NS
1/4-mile run/walk (min)	1047	2.3 ± 0.1	2.3 ± 0.0	2.4 ± 0.0	2.6 ± 0.1	< 0.001	NS	NS	NS	< 0.001	< 0.001	NS
1/2-mile run/walk (min)	976	5.3 ± 0.1	5.0 ± 0.0	5.5 ± 0.1	5.9 ± 0.2	< 0.001	NS	NS	NS	< 0.001	< 0.001	NS
1-mile run/walk (min)	880	11.5 ± 0.3	11.0 ± 0.1	11.9 ± 0.2	12.6 ± 0.4	< 0.001	NS	NS	NS	< 0.001	< 0.001	NS
Boys												
20mSRT (stages)	1387	4.8 ± 0.2	5.1 ± 0.1	4.0 ± 0.1	3.1 ± 0.2	< 0.001	NS	0.012	< 0.001	< 0.001	< 0.001	< 0.001
1/4-mile run/walk (min)	1380	2.2 ± 0.1	2.0 ± 0.0	2.1 ± 0.0	2.4 ± 0.0	< 0.001	0.001	NS	0.009	< 0.001	< 0.001	< 0.001
1/2-mile run/walk (min)	1271	4.5 ± 0.1	4.3 ± 0.0	4.8 ± 0.0	5.4 ± 0.1	< 0.001	NS	NS	< 0.001	< 0.001	< 0.001	< 0.001
1-mile run/walk (min)	1162	9.9 ± 0.2	9.4 ± 0.1	10.4 ± 0.1	11.3 ± 0.2	< 0.001	NS	NS	< 0.001	< 0.001	< 0.001	0.002

NS indicates non significant, P > 0.05.

Table III
Smoothed and age- and sex-specific percentile values for aerobic performance tests in girls aged 6-17 years

	n	10th	20th	30th	40th	50th	60th	70th	80th	90th
20m shuttle run (stages)										
6-7	192	0.3	0.5	0.8	1.2	1.7	2.3	3.0	4.0	5.1
8-9	276	0.4	0.6	1.0	1.5	2.1	2.9	3.8	5.0	6.5
10-11	227	0.4	0.7	1.2	1.8	2.5	3.5	4.8	6.3	8.1
12-13	219	0.5	0.9	1.4	2.2	3.1	4.3	5.8	7.6	9.8
14-15	126	0.4	0.8	1.4	2.2	3.2	4.4	5.9	7.6	9.6
16-17	133	0.4	0.8	1.3	2.1	3.0	4.1	5.4	6.9	8.6
1/4-mile (min)										
6-7	173	3.8	3.3	2.9	2.6	2.3	2.2	2.0	1.9	1.7
8-9	266	4.4	3.5	3.0	2.6	2.3	2.1	1.9	1.7	1.6
10-11	222	4.7	3.5	2.8	2.4	2.1	1.9	1.7	1.5	1.4
12-13	247	4.6	3.3	2.6	2.2	1.9	1.6	1.5	1.3	1.2
14-15	128	4.3	3.2	2.6	2.2	1.8	1.6	1.4	1.3	1.2
16-17	130	4.2	3.3	2.7	2.3	2.0	1.7	1.5	1.4	1.2
1/2-mile (min)										
6-7	157	8.4	7.1	6.2	5.6	5.1	4.7	4.3	4.1	3.8
8-9	249	9.5	7.6	6.5	5.6	5.0	4.5	4.2	3.8	3.6
10-11	202	9.4	7.6	6.3	5.4	4.8	4.3	3.9	3.5	3.3
12-13	218	8.7	7.1	5.9	5.1	4.4	3.9	3.5	3.2	2.9
14-15	122	8.4	7.0	5.9	5.1	4.4	3.9	3.5	3.1	2.8
16-17	131	8.1	6.8	5.9	5.1	4.4	3.9	3.5	3.1	2.8
1-mile (min)										
6-7	101	16.0	14.7	13.4	12.2	11.1	10.0	8.9	8.0	7.0
8-9	221	17.3	15.5	13.9	12.5	11.2	10.0	8.9	8.0	7.1
10-11	204	18.0	15.6	13.7	12.0	10.6	9.4	8.4	7.5	6.7
12-13	203	18.2	15.4	13.2	11.4	10.0	8.8	7.8	7.0	6.3
14-15	122	17.9	15.2	13.1	11.4	10.0	8.8	7.8	7.0	6.2
16-17	128	16.9	14.8	13.0	11.4	10.0	8.9	7.8	6.9	6.2

Smoothed age- and sex-specific percentiles for the fitness tests in girls and boys are presented in table III and IV, respectively. There was a trend towards increased aerobic performance level in boys as their age increased, whereas in girls, the performance in all the selected tests seem to achieve a plateau already at 12-13 years.

Discussion

There is increasing evidence indicating that fitness is a powerful indicator of health in youngsters.[2,3] Despite the important diagnostic information that can be provided by fitness tests, its use is often ignored in schools and clinical settings. The present study provides percentile values of four aerobic performance tests in children aged 6 to 17.9 years. Having percentile values of the most used field tests to measure aerobic performance in young people may help to identify children and adolescents at risk for the major public health diseases, as well as to evaluate the effects of alternative interventions. In this regard, schools may play an important role. Firstly by identifying children with low fitness levels, and secondly by promoting positive

Table IV
Smoothed and age- and sex-specific percentile values for aerobic performance tests in boys aged 6-17 years

	n	*10th*	*20th*	*30th*	*40th*	*50th*	*60th*	*70th*	*80th*	*90th*
20m shuttle run (stages)										
6-7	201	0.2	0.5	0.8	1.2	1.9	2.8	4.0	5.5	7.4
8-9	317	0.3	0.6	1.1	1.8	2.7	3.9	5.3	7.0	9.0
10-11	277	0.2	0.7	1.4	2.3	3.3	4.6	6.1	7.7	9.5
12-13	285	0.2	0.9	1.9	3.1	4.5	6.0	7.7	9.5	11.4
14-15	159	0.2	1.2	2.5	3.9	5.5	7.2	9.0	10.9	12.9
16-17	185	0.4	1.5	2.8	4.2	5.8	7.4	9.1	10.9	12.8
1/4-mile (min)										
6-7	200	3.9	3.3	2.9	2.5	2.3	2.0	1.9	1.7	1.6
8-9	314	3.8	3.2	2.8	2.5	2.2	1.9	1.7	1.5	1.4
10-11	277	3.4	3.0	2.6	2.3	2.0	1.7	1.5	1.3	1.1
12-13	312	3.1	2.6	2.2	1.9	1.7	1.5	1.3	1.2	1.0
14-15	158	3.0	2.3	2.0	1.7	1.5	1.3	1.2	1.1	1.0
16-17	182	3.3	2.3	1.9	1.6	1.4	1.3	1.2	1.1	1.1
1/2-mile (min)										
6-7	172	8.5	7.0	6.0	5.3	4.8	4.4	4.0	3.7	3.5
8-9	298	8.3	6.8	5.8	5.1	4.6	4.1	3.8	3.5	3.2
10-11	240	7.9	6.5	5.6	4.9	4.3	3.9	3.5	3.2	3.0
12-13	275	7.1	5.9	5.0	4.3	3.8	3.5	3.1	2.9	2.7
14-15	155	6.7	5.4	4.5	3.9	3.5	3.1	2.9	2.6	2.5
16-17	181	6.5	5.1	4.3	3.7	3.3	3.0	2.7	2.5	2.4
1-mile (min)										
6-7	116	15.7	14.2	12.8	11.5	10.3	9.3	8.3	7.4	6.6
8-9	280	16.2	14.4	12.7	11.3	10.0	8.8	7.8	6.9	6.1
10-11	238	16.6	14.3	12.4	10.8	9.5	8.4	7.4	6.6	5.9
12-13	253	16.1	13.3	11.3	9.8	8.6	7.7	6.9	6.2	5.7
14-15	150	15.5	12.2	10.2	8.8	7.8	7.1	6.5	6.0	5.6
16-17	183	14.3	11.1	9.3	8.2	7.4	6.8	6.4	6.0	5.6

health behaviours, such as encouraging children to engage in physical activity, and decrease time in sedentary activities. The leadership of schools, as a powerful setting to promote a healthy lifestyle among young populations, has been recently highlighted by the American Heart Association.[14]

The findings presented in this study confirm the frequently observed sex differences in aerobic performance. Boys had better performance than girls in all ages and in the four studied fitness tests. These differences became greater with increasing age. Ortega et al.[15] reported that female adolescents aged 13-18 years had worse performance in the 20mSRT than males had. Similar results were reported in a sample of undernourished rural primary school children aged 7-14 years when performing the 1-mile test.[16] Aerobic performance increased with age in boys, whereas in girls, it increased up to 12-13 years, and after that all the studied tests tended to achieve a plateau. These results are consistent with those reported in other studies.[14,17] These sex differences might be due to physical developmental factors such as sex-related changes in lean body weight and body fat during puberty,[18] haemoglobin concentration,[19] or hormonal changes.[20] The fact that girls are less active than boys might be another factor explaining these differences.[21]

We compared the levels of aerobic performance measured by the 20mSRT with 14 studies carried out in 11 different countries: Belgium,[22] Finland,[23] Republic of Seychelles,[24] Denmark,[25,26] United Kingdom,[27] Greece,[28] Spain,[15] Netherlands,[29] Sweden,[30] Portugal,[31] and North America[32]. The children in our study had better performance than their age-matched peers from Greece and Portugal, whereas better scores were reported in the rest of studies. These data confirm the results of Olds et al.[17] who also showed that Mediterranean children seem to perform worse on aerobic performance tests relative to their peers from other European countries. Further, these countries have also the highest levels of obesity.[33] The consequences of having low fitness and high fatness in these ages and later in life are well known, therefore, the situation calls for urgent action.

Results of the present study also indicated that overweight and obese children had worse performance on all tests compared with their normalweight counterparts. These data are consistent with other studies conducted among school-aged children, showing that overweight and obesity was inversely related to fitness in both girls and boys.[23,24,34-37] In Canadian children aged 8-10 years, low levels of aerobic performance was associated with overweight and obesity in boys but not in girls,[25] whereas in Portuguese children aged 8-10 years, these differences were much more pronounced in girls than boys.[38] We also observed that underweight children had similar performance than their normal-weight counterparts, and underweight boys had better performance than their obese counterparts. Others reported similar observations, assessing aerobic performance by the 20mSRT.[16,24,37,39].

The poorer performances in overweight and obese children are probably due to the fact that the higher body weight is an extra load to be moved during weight-bearing tasks. Differences in body composition among weight status groups may also explain the differences observed in the performance. Unfortunately, body composition data are not available in this study, which hamper further comparisons. Moreover, overweight and obese children seem to avoid weight-bearing activities because of the greater energy cost compared with non-overweight/obese counterparts.

Several studies have shown the validity of the 20mSRT[11,40,41] and 1-mile tests,[42,43] whereas studies examining the validity of the 1/2-mile and 1/4-mile tests are lacking. We analysed the validity of the 1-mile test in children aged 8-17 years,[44] and we observed that one of the widely used equation to estimate VO_{2peak} in children, the Cureton's equation,[44] systematically underestimates VO_{2peak} in endurance trained children. Fernhall et al.[45] studied the validity of the 1/2-mile test and concluded that this test has a questionable validity as an indicator on cardiorespiratory fitness in children with mild and moderate mental retardation. We also analysed the validity of the 1/2-mile test in children aged 6-17 years.[46] We developed and cross-validated a regression equation for estimating VO_{2peak} from the 1/2-mile time, sex, and BMI. We did not observe a significant difference between measured and estimated VO_{2peak}, nor heteroscedascity, and an acceptable error was also reported.[46] Further, we showed that the new regression equation was more accurate than the Fernhall´s equation. To our knowledge, there are not data available regarding the validity of the 1/4-mile test. It has been suggested that in adolescents, field-running tests of aerobic performance should be at least 1/2 mile,[47] but ideally one mile or longer. For younger individuals, tests between 1/2 mile and 1 mile seems to be better predictors of aerobic performance.[48] Therefore, the 1/4-mile test might not be adequate test to assess aerobic performance in youth. However, the 1/4-mile distance is probably approaching the upper limit of maximal performance capabilities and motivation to perform in younger children. This issue warrants further investigation.

The limitations of this study include its cross-sectional nature. Level of fitness and fatness in growing children and adolescents should be obtained in longitudinal studies, which gives the possibility to assess natural changes in individual growth and development. It should also be recognized that the studied sample is not representative of the Spanish children and adolescent population; yet, our data are fully comparable with nationally representative data obtained from the AVENA study.[15,49] The large sample of children and adolescents aged 6 to 17.9 years measured together with several widely used tests to measure aerobic performance is a strength of this study.

Conclusions

Percentiles values of four aerobic performance tests are provided. The presented percentiles values will be of interest to classify youth, and to estimate the proportion of children with high or low aerobic performance levels. The level of aerobic performance of children and adolescents in the present study was worse than that of children and adolescents in other countries. Overweight and obese children have an impaired aerobic performance compared to their normalweight peers, which was not observed in underweight children. To note is that Mediterranean countries seem to have the lowest aerobic performance levels as well as the highest prevalence of overweight and obesity. Given that overweight and obesity and low aerobic performance levels are associated with increased cardiovascular risk factors in adolescence and later in life, effective measures, strategies and intervention programs are needed to prevent the increase of childhood obesity and to improve the fitness levels.

Acknowledgements

The study was funded by Centro Andaluz de Medicina del Deporte, Junta de Andalucía, Orden 4/02/05, BOJA nº 37 (Ref. JA-CTD2005-01), the Swedish Council for Working Life and Social Research, the Spanish Ministry of Education (EX-2007-1124, AP2004-2745) and the European Union, in the framework of the Public Health Programme (ALPHA project, Ref: 2006120) and the Spanish Ministry of Science and Innovation (RYC-2010-05957).

References

1. Taylor HL, Buskirk E, Henschel A. Maximal oxygen intake as an objective measure of cardio-respiratory performance. *J Appl Physiol* 1955; 8: 73-80.
2. Ortega FB, Ruiz JR, Castillo MJ, Sjostrom M. Physical fitness in childhood and adolescence: a powerful marker of health. *Int J Obes (Lond)* 2008; 32: 1-11.
3. Ruiz JR, Castro-Pinero J, Artero EG, Orgeta FB, Sjostrom M, Suni J et al. Predictive Validity of Health-Related Fitness in Youth: A Systematic Review. *Br J Sports Med* 2009; 43: 909-923.
4. Matton L, Thomis M, Wijndaele K, Duvigneaud N, Beunen G, Claessens AL et al. Tracking of physical fitness and physical activity from youth to adulthood in females. *Med Sci Sports Exerc* 2006; 38: 1114-1120.
5. Council of Europe Committee for the Development of Sport. EUROFIT: Handbook for the EUROFIT Tests of Physical Fitness. Strasbourg: Council of Europe; 1993.
6. Cooper Institute for Aerobics Research. The Prudential Fitnessgram: Test administration manual. 3rd ed. Champaign, IL: Human Kinetics; 2004.
7. Australian Council for Health Physical Education and Recreation (ACHPER). Handbook for the Australian Fitness Education Award manual. South Australia: ACHPER Publications; 1996.

8. The President's Council on Physical Fitness and Sport. The President's Challenge: The Physical Fitness Test. http://www.presidentschallenge.org/educators/program_details/physical_fitness_test.aspx Accessed October 4, 2007).
9. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* 2000; 320: 1240-1243.
10. Cole TJ, Flegal KM, Nicholls D, Jackson AA. Body mass index cut offs to define thinness in children and adolescents: international survey. *BMJ* 2007; 335: 194.
11. Leger LA, Mercier D, Gadoury C, Lambert J. The multistage 20 metre shuttle run test for aerobic fitness. *J Sports Sci* 1988; 6: 93-101.
12. Cole TJ, Freeman JV, Preece MA. British 1990 growth reference centiles for weight, height, body mass index and head circumference fitted by maximum penalized likelihood. *Stat Med* 1998; 17: 407-429.
13. Holm S. A simple sequentially rejective multiple test procedure. *Scand J Statist* 1979; 6: 65-70.
14. Pate RR, Wang CY, Dowda M, Farrell SW, O'Neill JR. Cardiorespiratory fitness levels among US youth 12 to 19 years of age: findings from the 1999-2002 National Health and Nutrition Examination Survey. *Arch Pediatr Adolesc Med* 2006; 160: 1005-1012.
15. Ortega FB, Ruiz JR, Castillo MJ, Moreno LA, Gonzalez-Gross M, Warnberg J et al. [Low level of physical fitness in Spanish adolescents. Relevance for future cardiovascular health (AVENA study)]. *Rev Esp Cardiol* 2005; 58: 898-909.
16. Monyeki MA, Koppes LL, Kemper HC, Monyeki KD, Toriola AL, Pienaar AE et al. Body composition and physical fitness of undernourished South African rural primary school children. *Eur J Clin Nutr* 2005; 59: 877-883.
17. Olds T, Tomkinson G, Leger L, Cazorla G. Worldwide variation in the performance of children and adolescents: an analysis of 109 studies of the 20-m shuttle run test in 37 countries. *J Sports Sci* 2006; 24: 1025-1038.
18. Krahenbuhl GS, Skinner JS, Kohrt WM. Development aspects of maximal aerobic power in children. *Exerc Sport Sci Rev* 1994; 22: 435-476.
19. Armstrong N, Welsman J. Physical activity and aerobic fitness. Young people and physical activity. Oxford: Oxford Medical Publications; 1997:369.
20. Tercedor P, Gonzalez-Gross M, Delgado M, Chillón P, Pérez I, Ruiz JR, et al. Motives and frequency of physical activity practiced in Spanish adolescents. The AVENA study [abstract]. *Ann Nutr Metab* 2003; 47: 499.
21. Armstrong N, Welsman JR. The physical activity patterns of European youth with reference to methods of assessment. *Sports Med* 2006; 36: 1067-1086.
22. Deforche B, Lefevre J, De Bourdeaudhuij I, Hills AP, Duquet W, Bouckaert J. Physical fitness and physical activity in obese and nonobese Flemish youth. *Obes Res* 2003; 11: 434-441.
23. Fogelholm M, Stigman S, Huisman T, Metsamuuronen J. Physical fitness in adolescents with normal weight and overweight. *Scand J Med Sci Sports* 2007.
24. Bovet P, Auguste R, Burdette H. Strong inverse association between physical fitness and overweight in adolescents: a large school-based survey. *Int J Behav Nutr Phys Act* 2007; 4: 24.
25. Brunet M, Chaput JP, Tremblay A. The association between low physical fitness and high body mass index or waist circumference is increasing with age in children: the 'Quebec en Forme' Project. *Int J Obes (Lond)* 2007; 31: 637-643.
26. Wedderkopp N, Froberg K, Hansen HS, Riddoch C, Andersen LB. Cardiovascular Risk Factors Cluster in Children and Adolescents with Low Physical Fitness: The European Youth Heart Study (EYHS). *Pediatr Exerc Sci* 2003; 15: 419-427.
27. Stratton G, Canoy D, Boddy LM, Taylor SR, Hackett AF, Buchan IE. Cardiorespiratory fitness and body mass index of 9-11-year-old English children: a serial cross-sectional study from 1998 to 2004. *Int J Obes (Lond)* 2007; 31: 1172-1178.
28. Nassis GP, Psarra G, Sidossis LS. Central and total adiposity are lower in overweight and obese children with high cardiorespiratory fitness. *Eur J Clin Nutr* 2005; 59: 137-141.
29. Twisk JW, Kemper HC, van Mechelen W. The relationship between physical fitness and physical activity during adolescence and cardiovascular disease risk factors at adult age. The Amsterdam Growth and Health Longitudinal Study. *Int J Sports Med* 2002; 23 (Suppl. 1): S8-14.
30. Westerstahl M, Barnekow-Bergkvist M, Hedberg G, Jansson E. Secular trends in body dimensions and physical fitness among adolescents in Sweden from 1974 to 1995. *Scand J Med Sci Sports* 2003; 13: 128-137.
31. Ribeiro JC, Leandro C, Guerra S, Oliveira J, Duarte JA, Mota J. Cardiorespiratory fitness level and cardiovascular risk factors in school-aged girls. *J Hum Mov Stud* 2003; 45: 257-272.
32. Janz KF, Dawson JD, Mahoney LT. Increases in physical fitness during childhood improve cardiovascular health during adolescence: the Muscatine Study. *Int J Sports Med* 2002; 23 (Suppl. 1): S15-21.
33. Lobstein T, Frelut ML. Prevalence of overweight among children in Europe. *Obes Rev* 2003; 4: 195-200.
34. Hussey J, Bell C, Bennett K, O'Dwyer J, Gormley J. Relationship between the intensity of physical activity, inactivity, cardiorespiratory fitness and body composition in 7-10-year-old Dublin children. *Br J Sports Med* 2007; 41: 311-316.
35. Ortega FB, Tresaco B, Ruiz JR, Moreno LA, Martin-Matillas M, Mesa JL et al. Cardiorespiratory fitness and sedentary activities are associated with adiposity in adolescents. *Obesity (Silver Spring)* 2007; 15: 1589-1599.
36. Ara I, Moreno LA, Leiva MT, Gutin B, Casajus JA. Adiposity, physical activity, and physical fitness among children from Aragon, Spain. *Obesity (Silver Spring)* 2007; 15: 1918-1924.
37. Artero EG, Espana-Romero V, Ortega FB, Jimenez-Pavon D, Ruiz JR, Vicente-Rodriguez G et al. Health-related fitness in adolescents: underweight, and not only overweight, as an influencing factor. The AVENA study. *Scand J Med Sci Sports* 2009.
38. Mota J, Flores L, Flores L, Ribeiro JC, Santos MP. Relationship of single measures of cardiorespiratory fitness and obesity in young schoolchildren. *Am J Hum Biol* 2006; 18: 335-341.
39. Kim J, Must A, Fitzmaurice GM, Gillman MW, Chomitz V, Kramer E et al. Relationship of physical fitness to prevalence and incidence of overweight among schoolchildren. *Obes Res* 2005; 13: 1246-1254.
40. Van Mechelen W, Hlobil H, Kemper HC. Validation of two running tests as estimates of maximal aerobic power in children. *Eur J Appl Physiol Occup Physiol* 1986; 55: 503-506.
41. Ruiz JR, Ramirez-Lechuga J, Ortega FB, Castro-Pinero J, Benitez JM, Arauzo-Azofra A et al. Artificial neural network-based equation for estimating VO2max from the 20 m shuttle run test in adolescents. *Artif Intell Med* 2008; 44: 233-245.
42. Cureton KJ, Warren GL. Criterion-referenced standards for youth health-related fitness tests: a tutorial. *Res Q Exerc Sport* 1990; 61: 7-19.
43. Vicent SD, Barker R, Clark M, Harrison J. A comparison of peak heart rates elicited by the 1-mile run/walk and the progressive aerobic cardiovascular endurance run. *Am Alliance Health Phys Educ Recreat Dance* 1999; 70: 75-78.
44. Castro-Piñero J, Mora J, Gonzalez-Montesinos JL, Sjostrom M, Ruiz JR. Criterion-related validity of the one-mile run/walk test in children aged 8-17 years. *J Sports Sci* 2009; 27: 405-413.
45. Fernhall B, Pitetti K, Stubbs N, Stadler JL. Validity and reliability of the 1/2-mile run-walk as an indicator of aerobic fitness in children with mental retardation. *Pediatr Exerc Sci* 1996; 8: 130-142.
46. Castro-Pinero J, Ortega FB, Mora J, Sjostrom M, Ruiz JR. Criterion related validity of 1/2 mile run-walk test for estimating VO2peak in children aged 6-17 years. *Int J Sports Med* 2009; 30: 366-371.
47. Cureton KJ, Boileau RA, Lohman TG, Misner JE. Determinants of distance running performance in children: analysis of a path model. *Res Q* 1977; 48: 270-279.
48. Stone WJ. Running tests for 7-9 years old children. *AAHPERD Symp Papers* 1978; 1: 54-57.
49. Moreno LA, Mesana MI, Fleta J, Ruiz JR, Gonzalez-Gross M, Sarria A et al. Overweight, obesity and body fat composition in spanish adolescents. The AVENA Study. *Ann Nutr Metab* 2005; 49: 71-76.