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Validity and reference values for the 3-minute shuttle run test in spanish preschoolers

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SUMMARY

OBJECTIVE: The purpose of this study was to analyze the validity and provide normative values for the three-min shuttle run test in Spanish preschoolers.

METHODS: A total of 497 children (mean age 4.83±0.57 years; 47.8% girls) performed the three-min shuttle run test. Posttest body mass index and heart rate values were taken as internal validity indicators.

RESULTS: Age- and sex-specific percentiles for cardiorespiratory fitness were provided. Boys performed better than girls in the test. A significant association was observed between the total distance covered and heart rate (p=0.002). No correlation was found between body mass index and the test score, although the total distance covered by normal weight and obese children was significantly different (296.9 *versus*. 271.3 m; p=0.013).

CONCLUSIONS: This study provides age- and sex-specific cardiorespiratory fitness normative values for the three-min shuttle run test when performed by Spanish preschoolers. This test is an interesting option when the lack of resources limits the measurement of cardiorespiratory fitness in the preschool setting.

KEYWORDS: Reference values. Cardiorespiratory fitness. Children. Spain.

INTRODUCTION

Cardiorespiratory fitness (CRF) is the most important marker for health and disease during childhood[1,2]. Thus, it seems important to track CRF during the early years and, consequently, include its assessment in health and educational monitoring systems.

To accurately fulfill this aim, meaningful, reliable, and sensitive outcome measures are required. In this regard, laboratory-based direct measures of this physiological variable are considered the gold standard for this purpose. However, the accuracy and utility of these tests for preschoolers have been questioned, given the smaller body size relative to the testing equipment, the reduced motivation, and the potentially shorter attention span[3].

In this context, field-based tests represent a practical and feasible option, due to their low cost and ease administration. However, as field-based tests are indirect, they must show adequate psychometric properties (i.e., reliability and validity) before they can be used for gathering valuable data. There are a reduced number of CRF field-based tests whose psychometric properties have been identified when performed by preschoolers. In their thorough revision of health-related physical fitness test for preschoolers, Ortega et al.[4] found five CRF tests whose reliability had been previously informed. However, their validity was unknown. To the authors' knowledge, up to date, the preschool-adapted 20-m shuttle-run test (from the PREFIT battery) is the only CRF test whose validity (convergent) was identified by comparing its results against the original 20-m shuttle run test[1].

However, there are two important facts that should be taken into account when administering this test to preschoolers.

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First, the utility for accurately identifying CRF through the estimation of maximal oxygen consumption in these shuttle-run tests has recently been seriously questioned[5]. Second, this test requires materials as well as human resources for its development. An area of more than 20 m length and audio system are required. Besides, it has been suggested that at least two adults must accompany children while running for an accurate performance[6]. These resource requirements and practical implementation issues that seem to appear when this test is carried out in the preschool setting negatively influence its scalability[7].

Contrary to this background, the three-min shuttle run test (3MSRT)[8] stands out as an interesting alternative option, since it requires minimal equipment, and it can be performed by the children themselves. Previous study has confirmed that this test is reliable in preschoolers[2,8,9]. In addition, the test has shown a significant association with the original 20-m shuttle run test, and it has also been identified as a more feasible option for assessing CRF in preschoolers[2]. In spite of the fact that the 3MSRT is still considered by researchers working in the field of preschoolers and health[10], it is not as widely used as the 20-m shuttle-run versions. This could be tied to the fact that no study has provided evidence regarding its validity and also to the lack of reference values that allow the categorization of children according to CRF levels.

Under these circumstances, this study had a twofold objective. First, it was aimed at providing sex-and-age-reference standards by gender and age for the 3MSRT when performed by Spanish preschool children. Second, the aim was to inform about its content validity when administered in this population.

METHODS

This study was performed using the data gathered by physical education students from February 2014 to March 2019, while doing their internship curriculum.

Participants

The participants were normal healthy Spanish urban children who were recruited from 12 different kindergartens in Northern Spain. Those who were between four and five years old and who did not show any medical problem that could affect the completion of the proposed measurement tests were deemed eligible for the study. Parental permission and child assent were obtained after stakeholders were informed that they could decide whether or not to take part in the study, what the objectives were, and the possible risks and benefits. The protocol of this study was approved by the Local Ethics Committee.

Measurements

- *Anthropometrics:* The weight (kg) and height (cm) of children were measured by means of a digital scale and a portable statimeter. The body mass index (BMI) was calculated dividing the body weight in kilograms by the height in meters squared (kg/m^2).
- *Cardiorespiratory Fitness:* For the 3MSRT, two poles (1.5 m in height) were placed 10 m apart to form a straight 10-m long running track. Children had to run from one side to the other, go around the pole, and then return to the starting point. They were encouraged to run as fast as possible and to stop as little as possible for three min. A tape measure was placed between the poles, to register the total distance covered, which is the test score.
- *Heart Rate:* Heart rate (HR) was registered two min before the test began (HR basal) and just after the test was finished (peak HR) by means of a HR monitor (Polar RS400, Kempele, Finland) connected *via* Bluetooth to an iPad Air 2.

Procedure

All tests were carried out on groups of 10–12 children during the psychomotricity sessions and daily break times in the kindergartens' facilities (gymnasium or school playground). Two evaluation sessions were carried out on alternate days of the same week. During the first session, BMI was measured, and the protocol of the test was explained and performed by the evaluator. Several trials were carried out by the children after observing the correct execution, in order for them to familiarize with the test protocol. The second session was devoted to perform the 3MSRT.

All the measurements were performed in each of the kindergarten, which were included in this study, by a preschool teacher and a physical education student who were previously trained in the performance of the test.

Statistical analysis

The data are expressed as mean±standard deviation for quantitative variables or as n (%) for qualitative variables. With the SPSS program, we compared categorical variables with the chi-square test and continuous variables with independent data Student's *t*-test or ANOVA (with Bonferroni correction for multiple comparisons), after assessing normality of the data using the Kolmogorov–Smirnov test. To estimate percentiles of the population results in the 3MSRT (stratified for age and sex), we used a subgroup size weighting to account for heterogeneity among subgroups of children from the different kindergartens included in this study. Additionally, to study internal validity of the 3MSRT, we used BMI and HR as the main comparison variables. A two-sided $p<0.05$ indicated statistical significance.

RESULTS

The final sample for this study included 497 children (mean age 4.83±0.57 years; 47.8% girls). The anthropometric and CRF values obtained by them (whole sample and separated by sex and age) are shown in Table 1. The prevalence of obesity and overweight reached around 30% values on the analyzed sample.

Boys significantly outperformed girls in the total distance covered in the 3MSRT, regardless of age. CRF was significantly higher in the five-year-old group in comparison with the four-year-old children, regardless of sex.

Table 2 shows the specific sex and age reference values according to 10th, 20th, 30th, 40th, 50th, 60th, 70th, 80th, and 90th percentiles. The total distance covered increased with age both in boys and girls, but significant differences ($p<0.001$) were only found between four and five years for boys and between boys and girls of both four–five-year olds (Figure 1).

A significant association was observed between the total distance covered and the heart rate registered in the children after finishing the test ($p=0.002$), as shown in Figure 2A. No correlation was found between BMI and the CRF of children, although a significant difference was observed when comparing the total distance covered by normal weight and obese children (296.9 m *versus* 271.3 m; $p=0.013$) as it can be observed in Figure 2B.

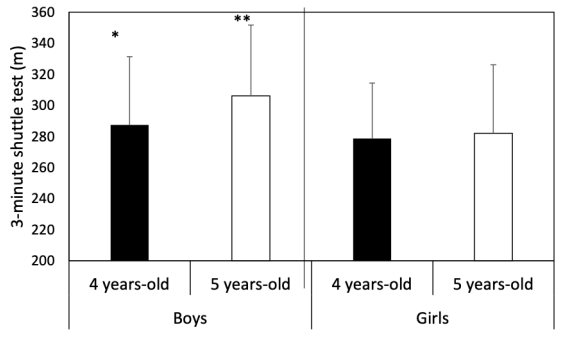
Table 1. General characteristics of the sample.

	Total sample (n=497)	Boys (52.2%)		Girls (47.8%)		Significant differences
		4 years old (38.4%)	5 years old (61.6%)	4 years old (44.2%)	5 years old (55.8%)	
Weight (kg)	20.42 (3.26)	19.1 (2.84)	21.42 (3.09)	18.95 (2.64)	21.53 (3.49)	Age**
Height (cm)	111.12 (6.64)	107.69 (4.79)	113.86 (6.54)	107.31 (4.73)	113.85 (6.64)	Age**
BMI (kg/m^2)	16.49 (1.70)	16.42 (1.72)	16.51 (1.71)	16.42 (1.55)	16.59 (1.9)	–
BMI categories (IOTF)						
Normal weight (%)	355 (71.4)	76 (80.9)	105 (69.5)	70 (70.7)	83 (66.4)	–
Overweight (%)	112 (22.5)	12 (12.8)	38 (25.2)	23 (23.2)	32 (25.6)	–
Obese (%)	30 (6)	6 (6.4)	8 (5.3)	6 (6.1)	10 (8)	–
Weighted 3MSRT (m)	289.38 (43.42)	287.41 (43.97)	306.14 (45.57)	278.67 (35.70)	281.99 (44.13)	Age** and sex**
Basal HR (bpm)	110.43 (10.46)	107.74 (11.36)	113.35 (10.89)	105.92 (8.49)	113.04 (8.99)	Age**
Maximum HR (bpm)	193.29 (10.16)	192.95 (9.32)	191.48 (10.71)	195.23 (10.24)	194.24 (10.0)	Sex*

Values are mean (standard deviation) or n (%). 3MWT: 3-min shuttle run test; BMI: body mass index; BPM: beats per minute; HR: heart rate; IOTF: international obesity task force. Differences by age and sex were analyzed with χ^2 test, Student's *t* test, or ANOVA, as appropriate. *p<0.05; **p<0.001.

Table 2. Meters completed in the 3-min shuttle run test by sex and age-weighted percentiles.

	Percentiles									
	n	10th	20th	30th	40th	50th	60th	70th	80th	90th
Total sample	497	240	260	270	280	288	296	310	320	344
Boys										
4 years old	94	230	255	270	280	285	296	310	320	340
5 years old	151	250	275	285	295	310	320	330	340	360
Girls										
4 years old	99	230	255	268	270	275	285	295	304	320
5 years old	125	224	250	270	275	285	290	300	315	340



*p<0.001 *versus* 5 years old; **p<0.001 *versus* girls. Bars represent mean, and error bars represent standard error.

Figure 1. Meters completed in the three-min shuttle run test by sex and age groups.

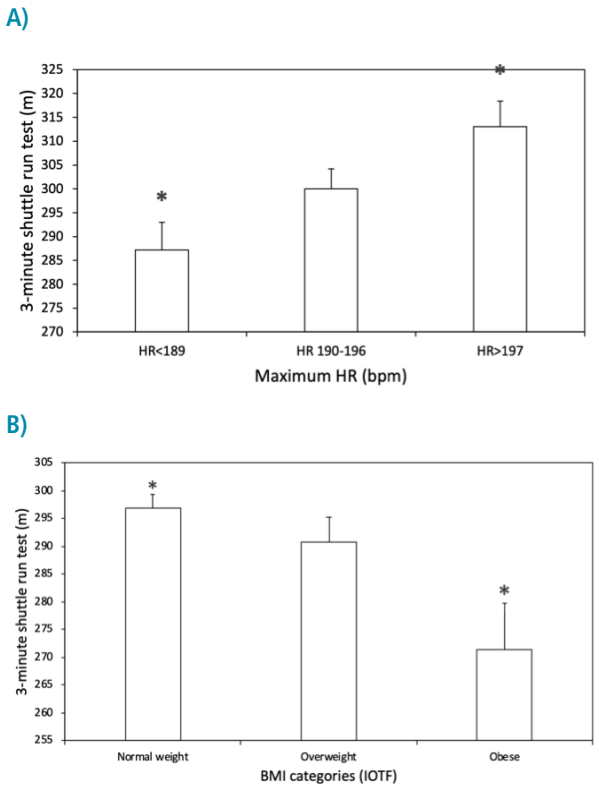


Figure 2. Distance covered in the three-min shuttle run test (m) according to **(A)** maximum HR achieved (*p=0.002 between children with HR<189 and HR>197) and **(B)** IOTF BMI categories (*p=0.013 between normal weight and obese children). Differences analyzed with ANOVA with Bonferroni correction. Bars represent mean, and error bars represent standard error. HR: heart rate in beats per min; BMI: body mass index; IOTF: International Obesity Task Force.

DISCUSSION

This study aimed at establishing reference values for the 3MSRT, as well at providing information regarding its content validity. Given the necessity to assess CRF in preschoolers, the data showed in this study can be of interest for physical education teachers and health practitioners.

Cardiorespiratory fitness reference values are necessary for detecting and monitoring the health of preschoolers, as well as to classify them based on their performance on field-based tests. In addition, normative data can help to set the bases for carrying out interventions aimed at developing the fitness level and the health status of children from an early age. To the authors' knowledge, only two very recent studies have provided reference values for CRF in preschoolers, as assessed by means of the adapted 20-m shuttle-run test[11,12]. Therefore, the present results add valuable information to the existing scientific body of knowledge.

The findings showed in this study are in line with previous observations regarding the significant impact that age and sex has on the preschoolers' CRF[1], which speak in favor of the 3MSRT discriminatory power.

We analyzed the relationship between the total distance covered in the test and the HR registered after its performance, as an indication of its content validity. The obtained results showed the existence of a significant association between both variables. In spite of the fact that this procedure for assessing the content validity of a CRF field-based test has been used in adult population[13], its accuracy could be criticized, on the basis that HR response to a maximal effort differs between children and adults. Nevertheless, when our statistical analysis was designed, we followed previous observations suggesting that those preschoolers with greater running ability would possess a more efficient cardiac function[14]. Our findings are in line with those obtained by Cadenas-Sánchez et al.[6], who after administering the adapted 20-m shuttle run test in preschoolers, it was observed that the greater the distance covered, the higher the HR. In this regard, we should acknowledge that peak HR values obtained in this study were lower than those observed in the original (4 bpm) and adapted versions (6–9 bpm) of the 20-m shuttle run test[1,6]. These differences, slightly higher for the adapted version than for the original one, could be due to adults running alongside the children, as suggested in the modified 20-m shuttle run protocol. Nevertheless, the mean HR peak values observed in our sample were much higher than those found by Mimura et al.[14] and Tuan et al.[3] in a sample of preschoolers who performed a submaximal cardiorespiratory laboratory test. These findings imply that the protocol of the 3MSRT demands maximal effort from the participant.

Body mass index has shown to significantly impact CRF in preschoolers[15,16]. Therefore, as a secondary indication of content

validity, we opted for analyzing the degree of association established between BMI values and the 3MSRT score. Contrary to what could be initially expected, no significant correlation was observed between both variables. Although we found that those children with lower BMI performed better in the test, the significant differences in the total distance covered were only registered between normal weight and obese preschoolers. A possible explanation for these results relies on previous observations suggesting that BMI might not be a good indicator of adiposity in preschoolers and that fat free mass index (FFMI) should be used instead[3]. In support of this assumption, Latorre-Román et al.[17] did not found any significant association between BMI and CRF fitness in preschoolers, while several studies have confirmed that preschoolers with higher FFMI show greater CRF[3,18]. Hence, the data on the accuracy of using BMI as an indicator of CRF field-based tests' content validity remain inconclusive.

There are some limitations that should be acknowledged. First, our sample was made up of Spanish urban preschoolers, which limits the generalization of the obtained findings. Second, we used BMI values for identifying the content validity of the test, instead of using FFMI, which seems a more accurate factor. Finally, although the data was obtained by different researchers previously familiarized with the study procedure, it should be acknowledged that inter-rater reliability was not assessed.

CONCLUSIONS

This research provides age- and sex-specific CRF normative values for the 3MSRT when performed by Spanish preschoolers. The obtained findings indicate that this test becomes an interesting option when the lack of resources limits the measurement of CRF in the preschool setting.

AUTHORS' CONTRIBUTIONS

JCD: Conceptualization, Formal Analysis, Writing – original draft. **MASL:**Writing – original draft. **RIML:** Data curation. **CA:** Conceptualization, Writing – original draft.

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