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DESIGN AND VALIDATION OF A CARDIORESPIRATORY CAPACITY TEST FOR PRESCHOOL CHILDREN

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ABSTRACT

This study aimed to validate the 10x20m test for children aged 3 to 6 years in order to analyse cardiorespiratory capacity. 298 children, 159 boys (age=57.84±10.25 months) and 139 girls (age=56.68±11.00 months), that were randomly selected from three schools in the southeast of Spain participated in this study. The 10x20m test was designed to evaluate aerobic endurance. The 6-minute walk test (6MWT) was selected and used for convergent validity. The analysis of reliability using a test-retest found no significant differences ($p \geq 0.05$). As for convergent validity between the 10x20m test and 6MWT, a Pearson correlation coefficient of $r = -0.657$, ($p < 0.001$) was found. The linear regression analysis yielded a $R^2 = 0.432$. Regarding gender and age influences, no significant differences ($p \geq 0.05$) for any variable according to gender were found, while significant differences were found ($p < 0.001$) in the 10x20m test between age sub-groups. The results showed that the 10x20m test obtained adequate parameters of reliability and validity in healthy children aged 3 to 6 years. Therefore, to assess cardiorespiratory endurance in preschool children this test is valid, reliable and easy-to-perform.

Key words: Cardiorespiratory endurance; Physical fitness; Preschool assessment; Validation.

INTRODUCTION

The importance of physical activity (PA) for health is well known and research has noted both physical and psychological benefits when children participate in PA (Janssen & LeBlanc, 2010; Ahn & Fedewa, 2011). Fitness, adiposity and body fat distribution during childhood have shown a high correlation with cardiovascular health in adulthood (Casajús *et al*., 2012). Additionally, cardiovascular fitness is a biomarker of health at all ages (Ortega *et al*., 2008). The physical condition components related to health are: cardiorespiratory capacity; musculoskeletal capacity; and body composition (Ruiz *et al*., 2009). Cardiorespiratory capacity, in particular, is strongly associated with health even at early ages, and is a determinant of cardiovascular risk in preschool children (Bürgi *et al*., 2011), and an early risk factor for obesity (Chinn, 2006). Nevertheless, cardiorespiratory fitness has been studied least in pre-schoolers (Ortega *et al*., 2015).

Despite the fact that a sedentary lifestyle at this age is a reality (De Bock *et al*., 2013), few studies analysed the physical fitness and PA of children in the age range three to six years

(Bürgi *et al*., 2011; Niederer *et al*., 2012). Numerous tests have been proposed and developed for assessing physical fitness in children (ALPHA; EUROFIT in the Council of Europe Committee for the Development of Sport, 1988). Nevertheless, these are usually inadequate to determine fitness in preschool children as they have difficulty following strict instructions. Limited information is available about the reliability and validity of fitness tests for preschool children (Ortega *et al*., 2015). In relation to cardiorespiratory fitness, Cadenas-Sánchez *et al*. (2014), employed the Leger Test for preschool children and experienced some problems with the application, because preschool children exhibited limitations in their space-time perception. This limitation makes the Léger test impractical and it has not been validated for preschool children.

Fulton *et al*. (2001) emphasise the need to develop valid measurement methods of PA and sedentary behaviour in children aged 2 to 5 years. In this line, some studies have proposed modified tests for evaluating fitness in pre-schoolers (Fjørtoft *et al*., 2011; Ayán, 2013), but none of them provide parameters for validity and reliability. In addition, most of the above-mentioned studies show serious constraints to be implemented in a school context; necessary space or absence of a recreational area. Therefore, to the best of the researcher's knowledge, no test has been adapted and validated for pre-schoolers.

Considering the above information, it seems necessary to establish reference values with regard to fitness and physical development in pre-schoolers. Therefore, the aim of this study was twofold: (1) to design a physical test to evaluate cardiorespiratory endurance in preschool children; and (2) to assess the validity of the proposed test "10x20m" for cardiorespiratory endurance evaluation in children 3 to 6 years of age.

METHODOLOGY

Participants

In this study, children (N=298) between the ages of 3 to 6 years participated, namely 159 boys (age: 57.84±10.25 months, body mass index [BMI]=16.81±2.26kg/m^2), and 139 girls (age 56.68±11.00 months, BMI=16.76±2.25kg/m^2). They were randomly selected from 3 conveniently sampled schools in the southeast of Spain. Inclusion criteria included children enrolled in preschool and who did not suffer from any physical and/or intellectual disabilities.

Measures and materials

The anthropometric parameters analysed included height (cm), measured with a stadiometer (Seca 222, Hamburg, Germany), and weight (kg) that was recorded with a Seca 634 (Hamburg, Germany). Body mass index (BMI) was calculated as weight (in kg) divided by height squared (in m), that is BMI=weight(kg)/height(m)². Cardiorespiratory endurance was assessed using the 10x20m test, inspired by the spatial structure of the Léger test (Léger *et al*., 1988), and based on the guidelines of the Spanish Athletics Federation (RFEA) for the endurance efforts of participants at this age. The test design took into account that the rules were very simple and the test had a playful motivation.

Materials required include a tape measure to mark the distances of the runway (20m), 2 boxes, 5 balloons and a stopwatch. It is a 20m shuttle test, in which participants have to move 5 balloons from Box A located at the one end to box B located at the opposite end. The total distance covered was 200m and timed from the signal "Go" until the last balloon was deposited. It did not matter if the balloon did not enter the box. If the balloon was dropped while moving, the participant had to pick it up and continue moving. Supervisors informed the participants that the balloons must be caught with both hands. The test allows running and walking. Only 1 measured trial was given and time was recorded in seconds to the first decimal.

The test score was the running time where a longer time indicated a lower performance. As a test for convergent validity, the 6-Minute Walk Test (6MWT) was used (Rikli & Jones, 2103). The 6MWT was designed originally for adults and measures aerobic endurance evaluated by the maximum distance covered on flat ground for 6 minutes following a standard protocol. In healthy children and adolescents, this test has been validated and standardised in international studies (Li *et al*., 2005; Geiger *et al*., 2007). Specifically, Li *et al*. (2005) included young children (14.2±1.2 years), and reported an intraclass correlation coefficient 0.94 (0.89–0.96; $p<0.05$). In addition, due to its ease of understanding and execution, it was the most feasible option at the time to establish convergent validity.

Procedure

Parents signed an informed consent form for the children to participate in this research. The standards of the Declaration of Helsinki (2013 version), and following the European Community's guidelines for *Good Clinical Practice* (111/3976/88 of July 1990), as well as the Spanish legal framework for clinical research on humans (Real Decreto 561/1993 on clinical trials), were adhered to. The Bioethics Committee from the University of Jaén (Spain), approved the study and the informed consent procedures. The appropriate permission was obtained from schools in this study.

Data were collected between March and April of 2014. The tests were performed at sport facilities of schools and on a flat non-slip surface. In the first session, pre-test data were recorded. Before the test, a warm-up was given consisting of 5 minutes of running and 5 minutes doing exercises for mobility and elasticity. The children performed a familiarisation trial followed by the 10x20m test. After 72 hours, the 6MWT was administered. A week later, a re-test of the 10x20m test was conducted with a sample of 92 children. The children were motivated and encouraged at all times during the execution of the tests.

Statistical analysis

Data for this study were analysed using the SPSS statistical program, v.19.0 for Windows (SPSS Inc., Chicago, USA). The level of significance was set at $p<0.05$. The results are shown by means of descriptive statistics that includes the mean, standard deviation and percentiles. Tests for normal distribution and homogeneity (Kolmogorov-Smirnov and Levene, respectively), were conducted on all the data prior to analysis. For the comparison between the genders, Student's t-test and analysis of variance (ANOVA) were used with the *post-hoc* Bonferroni adjustment test for the comparison of age groups. The reliability was analysed by pre-post-test through the Intra-class Correlation Coefficient (ICC), and the

Bland-Altman graphic. The convergent validity was calculated by Pearson's correlation. Furthermore, a Pearson correlation analysis between variables was performed. Finally, a linear regression between 10x20m and 6MWT was applied.

RESULTS

Table 1, Table 2 and Figure 1 show the results of the different variables according to gender and age groups.

Table 1. **VARIABLES ACCORDING TO GENDER**

Variables	**Gender** **Boys** Mean±SD	**Girls** Mean±SD	**p-Value**
Age (months)	57.84±10.25	56.68±11.00	0.350
BMI (kg/m^2)	16.81±2.26	16.76±2.25	0.858
10x20m test (sec.)	92.78±18.12	95.55±19.19	0.201

SD (standard deviation); BMI: body mass index

Table 2. **VARIABLES ACCORDING AGE GROUPS**

Variables	**Age** **3 years** Mean±SD	**4 years** Mean±SD	**5 years** Mean±SD	**6 years** Mean±SD	**p-Value**
Age (months)	43.92±2.28	54.03±3.75	65.71±3.46	74.78±3.57	**<0.001**
BMI (kg/m^2)	16.91±2.03	16.37±2.19	17.08±2.42	16.74±2.33	0.166
10x20m test (sec.)	109.07±18.01	96.90±16.33	84.12±12.29	78.81±13.26	**<0.001**

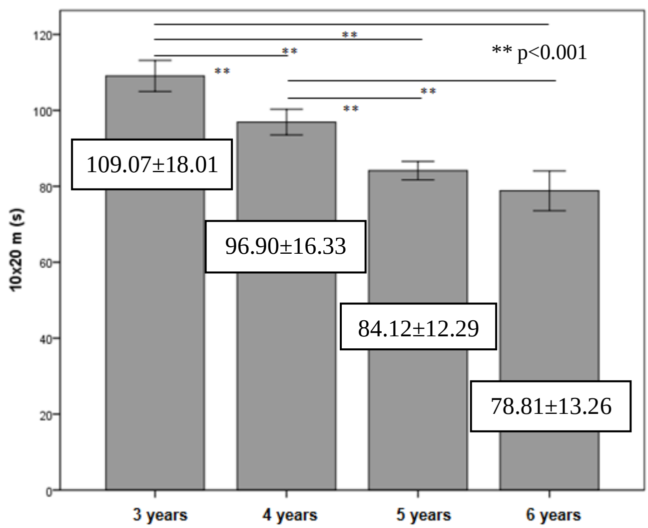

Figure 1. **RESULTS FOR 10X20M SHUTTLE ACCORDING TO AGE**

No significant differences (p≥0.05) for any variable according to gender were found. There were significant differences (p<0.001) in the 10x20m test between some age groups, where no significant differences were found between 5- and 6-year-olds. In addition, the Pearson correlation analysis showed that age significantly correlated with the 10x20m test (r=-0.617, p<0.001). The 10x20m test showed no significant correlation with BMI.

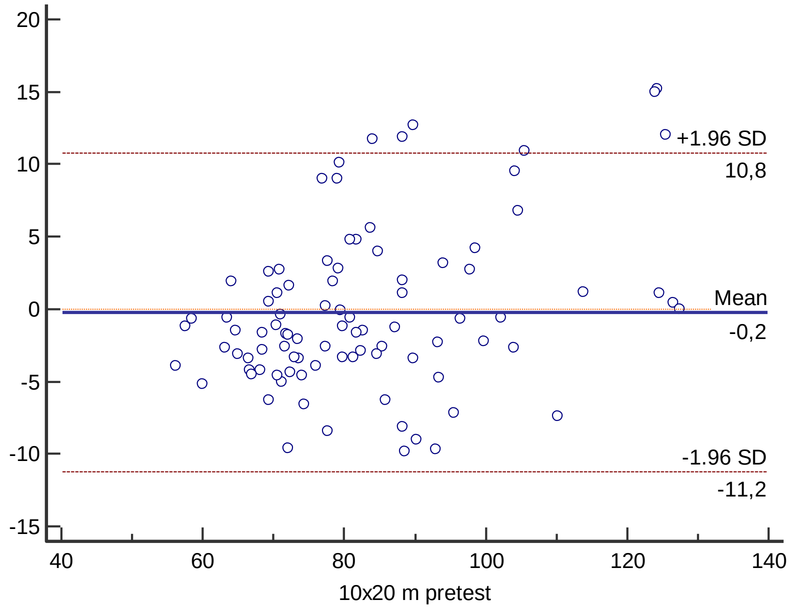

Figure 2. **10X20M PRE- POST-TEST**

In the analysis of reliability using a test-retest, the following results were obtained for the pre-test (mean=83.11±16.64s) and the retest (mean=83.31±15.48s), with no significant differences (p≥0.05) and an ICC=0.969, 95% confidence interval=0.953 to 0.979. The Bland-Altman graphic (Figure 2) presents the limits of accordance (±1SD) of 10.8 and -11.2s, with a mean difference of -0.2.

Regarding the convergent validity between the 10x20m test and the 6MWT, a Pearson correlation coefficient of r=-0.657, that was significant (p<0.001), was found. The linear regression analysis yielded a R^2=0.432 (Figure 3).

In Table 3, the different percentiles are provided for the 10x20m for the different age groups. The 50th percentile was 107.10 for the 6-year-olds, 95.05 for the 5-year-olds, 83.00 for the 4-year-olds and 79.30 for the 3-year-olds.

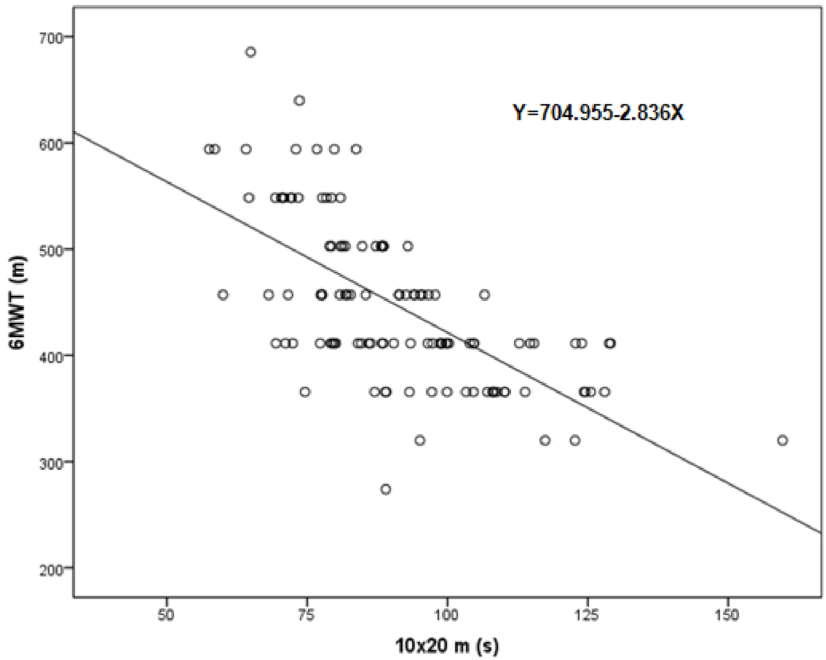

Figure 3. **LINEAR REGRESSION BETWEEN 10X20M AND 6MWT**

Table 3. **PERCENTILES BY AGE GROUP FOR 10X20-METRES SHUTTLE TEST**

	Percentiles						
Age groups	**5**	**10**	**25**	**50**	**75**	**90**	**95**
3-year-olds	84.76	87.60	96.75	107.10	122.10	129.44	136.20
4-year-olds	72.58	77.49	86.00	95.05	106.75	115.85	129.42
5-year-olds	66.51	70.10	76.65	83.00	90.00	97.16	105.73
6-year-olds	57.90	62.18	67.00	79.30	86.00	99.64	104.18

DISCUSSION

The evaluation of an individual response to exercise is an important and useful clinical tool because it provides a review of the respiratory, cardiac and metabolic systems (Li *et al*., 2005), and it is of particular relevance in children three to six years old. Higher levels of cardiorespiratory endurance in childhood and adolescence are associated with healthier cardiovascular profile in the future (Ruiz *et al*., 2009). Therefore, the evaluation of this capability is needed from early ages. The absence of specific tests validated for children three to six years old prompted this study to focus on the design and validation of a test for cardiorespiratory endurance in this age group.

The results indicate adequate reliability and validity parameters for the 10x20m test in healthy three to six years old children. A test cannot be valid unless it is reliable, that is, with repeated administration of the test and the same participants, the results should be comparable and should not be influenced by irrelevant or random factors, such as time of day, motivation, fatigue or boredom (Fjørtoft *et al*., 2011). A high temporal reliability (test/retest) and convergent validity between the 6MWT and 10x20m test was found. Therefore, this test has been shown to be safe, easy to perform and highly acceptable for preschool children. Therefore, the 10x20m test becomes a test, which provides a simple and inexpensive tool to measure cardiorespiratory endurance.

The 10x20m test also correlated significantly with age and it can be a test for monitoring the development of cardiorespiratory endurance in children of this age. In this regard, the time spent is reduced with increased age. Likewise, no significant differences between genders were found. As for the 6MWT, Lammers *et al*. (2008) reported similar results with children aged between 4 and 11 years. Unlike other studies of children between 7 to 12 years of age (Sugiyama & Hamlin, 2013; Tambalis *et al*., 2013), in which BMI inversely correlated with physical endurance and with cardiorespiratory capacity in particular. In the current study, the 10x20m test had no significant correlation with BMI. However, other authors (Niederer *et al*., 2012) pointed out differences between groups of normal weight, overweight and obesity in physical conditions including cardiorespiratory endurance, and note that such differences may be present in preschool children.

The most important limitation of this study lies in the fact that it was not feasible to obtain a direct measure of maximal oxygen consumption (VO_{2max}) for convergent validity. It is recommended that further research be undertaken in the same line, trying to achieve a larger sample of children to ensure a standardisation of the test and the establishment of normative values according to age and gender.

CONCLUSIONS

The results obtained in the current study show that very good parameters of reliability and validity were obtained for the 10x20m test in children aged 3 to 6 years. The tests used are safe, easy to perform, very acceptable and appropriate for children of this age group.

The relationship between cardiovascular fitness and health at all ages has been widely established and supported. Considering this statement, it seems surprising that sedentary lifestyle during childhood is an essential reality. Additionally, just a few studies have focused on analysing the physical fitness of children aged 3 to 6 years, probably due to the difficulty of assessing such young children. In fact, to the best of the researcher’s knowledge, no previous studies have validated a physical test for assessing fitness in children at these ages. Therefore, from a practical viewpoint, this study presents a valid, reliable and simple test to assess cardiorespiratory endurance in preschool children that can be an easy indirect way to examine the health of preschool children. Teachers, coaches, trainers or any other staff working with children of these ages can administer this test without needing an abundance of material and technological resources.

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