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Reference for the six minutes' walk test for children 4 to 10 years old
Referencia del test de caminata de seis minutos para niños de 4 a 10 años
Running head: Percentiles six minutes' walk test

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Abstract. Introduction: Physical activity is important for health. The six minutes' walk test is a simple measurement; whose importance is that can be applied to healthy children and some sick subjects. Objective: To generate a reference for the six minutes' walk test in children 4 to 10 years old. Methods: Cross-sectional study in a sample of 1420 boys and girls, aged four to ten years, attending public, subsidized and private schools in the commune of Santiago de Chile. The six-minute test was used to construct the percentile distribution of the six-minute walk test. Results: A table was generated with the percentile distribution for children aged 4 to 10 years according to age and nutritional status to have a reference for the six-minute walk test in this age group. Conclusion: This investigation provides a way to obtain a reference that can be used to follow up boys and girls of similar age and nutritional status, over time.
Key words: Six minutes' walk, percentile, submaximal exercise.

Resumen. Introducción: La actividad física es un pilar importante para la salud. La prueba de caminata de seis minutos es una medida simple; cuya importancia radica en que se puede aplicar a niños sanos y algunos sujetos enfermos. Objetivo: Generar valores de referencia para el test de caminata de seis minutos de niños y niñas de 4 a 10 años. Métodos: Estudio transversal en una muestra de 1420 niños y niñas, de cuatro a diez años de edad, asistentes a escuelas públicas, subvencionadas y privadas de la comuna de Santiago de Chile. Se utilizó el test de seis minutos para elaborar la distribución percentilar de la prueba de caminata de seis minutos. Resultados: Se generó una tabla con la distribución percentilar para niños de 4 a 10 años según edad y estado nutricional para disponer de una referencia para la prueba de caminata de seis minutos en este grupo etario. Conclusión: Este trabajo proporciona una forma de obtener una referencia que puede servir para el seguimiento de niños y niñas de edad y estado nutricional similar, a lo largo del tiempo.
Palabras claves: Test seis minutos, distribución percentilar, ejercicio submáximo.

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Introduction

The six minutes' walk test is a safe, a low cost, feasible, easy, valid and reproducibility method to assess functional walk capacity during six minutes period in children (Keil et al., 2021; Blanco et al., 2017; Watanabe et al., 2016; Geiger, 2007). This test is submaximal, thus apt to use in young age children and it measures the distance walked during the period of six minutes.

The six minutes' walk test (6MWT) proved to be easy to perform, and highly acceptable for children and adolescents. Children are eager to perform this test, due to its protocol that does not engage children in a strenuous exercise. It is particularly adequate for children 4 to 10 years old, which are not able to perform other more demanding tests. Additionally, it is indicated for children with physical impairment and the main work has been done in these children.

Li AM et al. proved the validity and reliability of the six-minute walk test in children. In addition, Bland and Altman plots demonstrated a high degree of repeatability (Li et al., 2005). Children length has shown to influence the results of the test (Oliveira et al., 2013). On the other hand, no training is required but encouragement along the test is needed (Morales et al., 2018; Boucalt et al., 2013).

There are several studies providing references from three to 18 years of age (Mylius et al., 2016; Chen et al., 2015), generated a reference based in several studies (De Miguel-Etayo el al., 2014) for children less than 18 years of age (Ulrich et al., 2013).

A reference study for the 6MWT generated in Swiss children 5 to 17 years of age for the 6MWT. The 6 minutes' walk test distance is linked to height, weight and heart rate after the test (Ulrich et al., 2013). The 6MWT distance depends mainly on age; however, heart rate after the 6MWT, and height and weight add significantly information and should be taken into account.

The result of the test reflects the integrated exercise response involving the pulmonary and cardiovascular systems, systemic and pulmonary circulations, and neuromuscular function. Thus, this test although submaximal is functional as reflects a variety of systems in the body.

The importance of this test is that can be applied to healthy children and some sick subjects.

The aim of this study is to generate a reference for the six minutes' walk test in children four to 10 years old.

Materials and methods

Subjects

Subjects

A sample of 1420 children was selected at random with ages from four to ten years old, as this period is important for

generating physical abilities and aptitudes. The 21 schools selected were public, subsidized and private located in the metropolitan area of Santiago, capital city of Chile. The sample consisted of 12 children per course selected at random in the class (6 per sex) in the ten levels measured. The total sample consisted of 2016 children, where 567 were excluded for having more than 10 years and 30 were excluded because they had incomplete data.

Methods

Anthropometry: weight and height were, measured according standard procedure, and measured with a scale especially for the age of children, a stadiometer SECA. Weight was measured up to one-gram error and height to the nearest 0,5 cm. Weight (K) and height (cm) were measured in the morning with minimal clothing (underwear only) (de Onis et al., 2013).

Children from four to 10 years old, healthy, whose parents signed the informed consent, were included in the sample.

Children with cardiorespiratory problems, physical inability to walk, influenza in the previous days, or use of medicines, which could affect physical activity performance were excluded.

Six minutes' walk test. The American Thoracic Society has established a guideline for implementing the test (ATS Committee 2002; Wilasco et al., 2012). In 30 m distance children walked until covering six minutes, in a continuous rhythm; but children could stop during the period covering the time and continue walking afterwards.

The children were advised to dress comfortably with appropriate footwear. A light breakfast was recommended as the test was conducted in the morning. Children did not engage in strenuous exercise for two hours prior to testing. The test was conducted in 30 meters, flat distance located in the schoolyard, which had no obstacles.

In addition, a Polar watch was installed in the chest of 50% of the sample, which were selected at random from the whole sample, and remained in the chest before the test, during the test and one minute post-test

The Ethical Committee of the University of Chile approved all procedures.

Statistics

Numerical variables that showed a normal distribution were expressed as mean and standard deviation. T Student Test was utilized for testing the comparisons in normal distributions.

Percentiles represent the area under the normal curve, increasing from left to right. Each standard deviation represents a fixed percentile. The percentile description was done using percentile distribution at 10th, 25th, 50th, 75th and 90th. The 20th percentile is the value below which 20% of the observations may be found. Statistical analysis was done with STATA 16 and significant differences were established at $p< 0.05$.

Results

In Table 1, the differences in age, weight, height and BMI between preschool and schoolchildren are shown. Differences in BMI reach 16.9 ± 2.1 in preschool children and 18.3 ± 3.1 in school children, ($p<0.01$).

Table 1.
Anthropometric data of sample (mean ± standard deviation)

	Age (y)	Weight (kg)	Height (cm)	BMI (k/m²)	WAZ	WHZ	HAZ	BMIZ
All (n 1419)	7.6±1.7	28.5±8.5	124.4±11.2	18.1±2.9				
Preschool (n 199)	5.2±0.5*	20.6±3.6#	109.91±5.3&	16.9±2.1$	0.8±1.3	1.2±1.7	0.0±1.1	
School (n 1220)	8.2±1.3*	30.5±8.3#	127.9±9.9&	18.3±3.1$		1.5±2.1	0.1±1.0	1.5±1.7

BMI: Body Mass Index BMIZ WAZ WHZ HAZ *#&$p<0.01

In Table 2, the information on six minutes' walk test and heart rate are indicated. The main differences are between boys and girls, whereas boys have better performance in all variables of the test ($p<0.01$). In the distance walked the difference between girls (554.6 ± 71.4) versus boys (570 ± 80.1), differences which are significant, ($p<0.01$).

Table 2.
Six minutes' walk test information in preschool and school children by sex and school level.

	Distance (m)	Pretest HR	Minute 1 post HR	Minute 6 post HR
All (n 1419)	562.2±77.7	92.0±13.3	132.7±18.4	114.1±15.6
Boys (n 717)	570±80.1*	91.5± 3.3	130.9±19.1	113.1±15.3&
Girls (n 702)	554.6±71.4*	92.7±12.6	135±17.4	115.6±15.1&
Preschool	473.1±47.8	98.8±11.3	129.2±15.2#	113±12.7
School	584.2±65.7	90.3±13.3	133.4.1±17.6#	114.5.5±16.5

HR: Heart Rate *#&$p<0.01

In Tables 3 and 4, the results of the distance walked by age and sex are shown, in normal nutritional status (Table 3) and

overweight and obese children (Table 4). It is important to note that the reference starts from five years of age. Both tables could be a reference for the distance walked based on age and sex for children and nutritional status four to 10 years of age.

A percentile distribution was created in Tables 3 and 4, based on age and sex and, constituting a reference for evaluation of physical condition, for both normal nutritional status (Table 3) and for overweight and obese children (Table 4).

Table 3.
Distance walked (m) percentile for children with normal nutritional status by sex

	Age	n	p10	p25	p50	p75	p90
Boys (n 436)	4	35	365	405	426	467	503
	5	57	451	477	498	529	570
	6	88	474	494	524	567	599
	7	76	521	545	585	619	684
	8	60	522	583	615	630	691
	9	87	574	600	642	683	722
	10	33	567	614	634	685	750
Girls (n 387)	4	22	396	408	458	481	516
	5	53	422	447	480	525	563
	6	73	478	502	534	570	590
	7	71	513	536	569	609	628
	8	64	533	558	585	626	646
	9	82	565	592	617	660	682
	10	22	550	555	614	654	685

Table 4.
Distance walked (m) percentile for overweight and obese children by sex

	Age	n	p10	p25	p50	p75	p90
Boys (n 305)	5	32	391	427	462	507	518
	6	50	475	494	541	561	590
	7	61	506	520	561	586	608
	8	61	510	553	589	623	645
	9	66	517	559	617	645	673
	10	26	545	591	613	649	724
Girls (n 292)	5	33	424	466	487	508	527
	6	31	457	480	510	556	575
	7	49	480	534	558	585	609
	8	56	485	532	566	602	616
	9	59	509	545	585	612	630
	10	32	554	573	609	645	656

Discussion

Childhood obesity is considered a multifactorial pathology influenced by genetic, biological, psychosocial, and behavioral factors (Russell & Russell, 2019). Energy imbalance, resulting from caloric intake exceeding energy expenditure, is one of the main determinants of overweight and obesity (Smith, Fu, & Kobayashi, 2020). Moreover, environmental and socioeconomic factors also play a crucial role in the prevalence of these conditions (Ortiz-Sánchez et al., 2021).

In a longitudinal study conducted in Spain, 70 children were evaluated over five years to determine the effects of overweight and obesity on body composition, physical function, and academic performance (Ortiz-Sánchez et al., 2023). Variables such as Body Mass Index, percentage of body fat, and muscle mass were measured, along with physical function through tests of jumping, agility, and handgrip strength. The results showed that overweight or obese children had poorer body composition, with higher body fat indices and lower percentages of muscle mass (Ortiz-Sánchez et al., 2023). Additionally, these children exhibited lower physical capacity, evidenced by poorer performance in jumping and agility tests. However, it was found that children with higher adiposity had greater handgrip strength, possibly due to higher lean tissue (Thivel et al., 2016).

These findings align with previous studies demonstrating that overweight and obese children have lower physical capacity and higher long-term health risks (Caprio, Santoro, & Weiss, 2020; Seo et al., 2019). Additionally, it has been observed that overweight and obesity can negatively affect academic performance due to factors such as low self-esteem and attendance problems (Seth, 2020). Few studies have analyzed this issue longitudinally. Only a few studies, such as those by García-Hermoso and Martínez-Gómez (2021) and Ma and Gao (2020), have shown that academic performance is better for students with adequate weight over two consecutive years; however, these studies did not account for changes in educational stages. Current evidence on the impact of overweight and obesity on academic performance has been inconsistent. A systematic review conducted in 2017 demonstrated that causal relationships between overweight, obesity, and academic performance were imprecise (Santana et al., 2017).

One study, conducted by Fierro Saldaña and Rocuant Urzúa (2023), aimed to establish a predictive model of physical condition in Chilean adolescents using BMI and socioeconomic level as variables. Utilizing the logistic regression method and data from the Physical Education Quality Measurement System (SIMCE), the study found that the likelihood of having a satisfactory physical condition decreases by 90.84% for students with a BMI above the average compared to those below the average. Additionally, students from medium, medium-high, and high socioeconomic groups have a 38.88% higher chance of having a satisfactory physical condition compared to those from lower socioeconomic groups.

Another study evaluated exercise in Chilean schoolchildren during physical education classes, assessing the relationship between physical education classes and the physical condition of children based on their weight status. Using accelerometers to measure body movements, it was found that normal-weight children had higher energy expenditure and engaged in more vigorous exercise compared to their overweight and obese peers. Normal-weight children also spent more time in vigorous activities and less in light activities during physical education classes compared to obese children (Tuesta et al., 2020).

The study focused on providing gender-specific percentile values of the COFISA test and their relation to weight status. The study concluded that boys generally showed higher physical performance than girls, except in flexibility and normal weight status where girls performed better. Normal-weight

boys and girls demonstrated better physical performance compared to their overweight and obese peers, highlighting the impact of BMI on physical fitness (Garcia Canto, 2020).

BMI is a significant predictor of physical condition. Higher BMI is associated with lower physical fitness levels, confirming the critical role of maintaining a healthy weight for overall physical health (Fierro Saldaña & Rocuant Urzúa, 2023). Students from higher socioeconomic backgrounds tend to have better physical conditions, emphasizing the need for policies that address these disparities to improve public health (Fierro Saldaña & Rocuant Urzúa, 2023). There are notable gender differences in physical fitness, with boys generally outperforming girls, although girls show superior flexibility and weight status performance in certain areas (Garcia Canto, 2020).

The findings from these studies highlight the importance of addressing both socioeconomic and physical health factors to improve the physical condition of students. The data suggest that policies and interventions aimed at reducing BMI and addressing socioeconomic disparities could significantly enhance the physical fitness and overall health of students, thereby reducing the risk of chronic diseases in adulthood. There are significant differences in weight, height, and BMI by school level (Vidarte et al., 2022). When making comparisons by sex, statistically significant differences are observed. Boys perform better than girls in aerobic fitness, results similar to those found in other studies (Vidarte et al., 2022).

Data on the six minutes' walk test (6MWT), according to nutritional status, is also included, showing a statistical difference among school levels (Pathare et al., 2012). Given the low physical activity of Chilean children (seven out of every ten children do not accomplish the minimum level of physical activity), it is suggested that the 50th percentile would be a minimum goal to accomplish for follow-up or in an intervention project.

The percentile distribution also allows for following up with children, due to physical activity interventions or school classification of their students before a more demanding test. A specific reference may not be adequate for a different population. For instance, reported values for the proposed Li et al. equation (6MWD = (4.63height (cm)) - (3.53weight(kg)) + (10.42*age) + 56.32) give a mean difference to our data of 49 meters, with two standard deviations reaching nearly 100 meters (Li et al., 2005). Similarly, a recent paper proposed an equation for under 18 years of age (Ulrich et al., 2013), which is based on age, weight, and height, giving a mean difference of 140 ± 63 meters, which is nearly a 20% difference to the values measured in Chile. In Chilean children, a percentile distribution is proposed, by sex and linked to age, variables that are strongly associated with the distance walked. Thus, it would help to classify a Chilean child or from any other origin, if mean weight, height, and age are similar. In this work, values of the 6MWT do not coincide with international papers, as the distance walked is smaller than the one reported in Li et al. with nearly a 100 meters difference, thus it is clear that children in Chile have different physical capacity or framework than children reported by Li et al. or other papers (Li et al., 2005; Mylius et al., 2016).

The 6MWT distance results reported by Lammers et al., who measured normal nutritional status English children aged four to 11 years, underestimate our results (Lammers et al., 2008). Priesnitz et al. generated an equation distance built in a sample of healthy children aged six to 12 years, which is as follows: 6MWT = 145.343 + (11.78 * age) + (292.22 * height) + (0.611*(HRfinal - HRbasal)) - 2.684 * weight, which gave results that are 23.2% higher than the 6MWT performance in Chilean children (Priesnitz et al., 2009).

The reference value for the 6MWT in children and adolescents ranged substantially from studies in different countries so an equation in this work is not provided (Cacau et al., 2016; Goemans et al., 2013; Ben Saad et al., 2009). Additionally, studies on the 6MWT should incorporate equations that make them amenable to comparison with other studies. The reference data presented in this work enable the assessment of the walked distance during six minutes, in children aged four to ten years. The most prevalent variables in reference equations are height, age, and weight, which is not surprising as they are the available variables linked to exercise performance (Lammers et al., 2008).

Finally, this work provides a way to obtain the distance walked plus a reference that can serve to follow up children of similar age over time. A strength is the sample size of children and highly trained nutritionists collected anthropometric determinations. One of the limitations was the selection of students. Only a group of students from one sector of Santiago participated in this study. Another limitation was the non-measurement of variables such as blood pressure or oxygen consumption.

Conflict of interest

The authors declare no conflict of interest.

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