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Original Article

Ten year trends in body composition and fitness of school children

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Abstract:
The physical fitness of children, including those from Brazil, has deteriorated in the last decades. Scientific literature lacks information on secular trends related to body composition and physical fitness of children, and available data is inconsistent. This study aimed to assess secular trends in physical fitness of children aged 6-10 years old. Evaluations were conducted with 339 (in 2006) and with 610 (in 2016) children aged 6-10 years old from a private school, assessing height, body weight, body mass index (BMI), triceps and subscapular skinfolds, percentage of body fat (%F), agility and cardiorespiratory fitness. In 2016, girls exhibited higher BMI, triceps skinfold and %F than boys. Over 10 years, height and body weight of girls and boys increased (4.1cm and 3.1kg in girls, 3.9cm and 1.5kg in boys, respectively, $p<0.05$). BMI did not change, nor did the prevalence of overweight and obesity, triceps skinfold and %F. Boys' agility was significantly higher than girls', in 2006 and 2016 ($p<0.001$). Girls and boys worsened 0.54% per year from 2006 to 2016. Boys' cardiorespiratory fitness was better than girls' in 2006 and 2016 ($p<0.001$), but there were no changes among girls. Decrease in aerobic fitness was 0.83% per year among boys. In conclusion, although the prevalence of overweight, excessive adiposity and obesity have not changed ialong 10 years, physical fitness has worsened. Results support recent data and reinforce the need for effective measures to face these declines as early as in childhood. Parents, teachers and health professionals must encourage a healthy lifestyle in children, especially concerning eating habits and an active behavior.
Keywords: **physical fitness, cardiorespiratory fitness, obesity, adiposity.**

Introduction

Nutritional status (**NS**) and physical fitness (**PF**) of children aged 6 to 10 years old, in several countries, including Brazil, have worsened in the last 40 years. Although height has shown a secular increase (IBGE, 2010), body weight (Albon *et al.*, 2008, Venckunas *et al.*, 2017), body mass index (**BMI**) (Tambalis *et al.*, 2011, Silveira *et al.*, 2014, Venckunas *et al.*, 2017) and body adiposity (Johnson et al., 2013, Dos Santos *et al.*, 2015) have also increased, resulting in growing prevalences of overweight (**OVW**) and obesity (**OBE**) (IBGE, 2010, Ng et al., 2014, NCD-Risk, 2017). In parallel, a secular trend for worse **PF** results has been observed (Tomkinson *et al.*, 2003, Albon *et al.*, 2008, Tambalis *et al.*, 2011, Dos Santos *et al.*, 2015, Venckunas *et al.*, 2017, Gaya *et al.*, 2020), yet a few studies have noticed better performance along the years (Moliner-Urdiales *et al.*, 2010, Smpokos *et al.*, 2012). **OVW** and **OBE**, defined as the excessive or abnormal accumulation of body fat that may be harmful to health, are a severe problem around the world, surpassing low body weight and malnutrition (WHO, 2018). The prevalence of **OVW** and **OBE** has been growing alarmingly and are considered pandemics (Ng *et al.,* 2014). These problems are not limited to developed countries, they are spreading over low income and developing countries as well (IBGE, 2010, Ng *et al.,* 2014, NCD-Risk, 2017).

Hygiene, nutrition and other conditions related to childhood diseases have improved, but the prevalence of **OVW** and **OBE** has increased (NCD-Risk, 2017), suggesting that quality and quantity of food, and levels of physical activity are not ideal (Rivera *et al*., 2014). **OVW** and **OBE** are among the leading causes of non-communicable chronic diseases (**NCCD**), lost days of work and deaths (WHO, 2018). These conditions result in adverse metabolic alterations such as high blood pressure, augmented cholesterol, triglycerides and insulin resistance. The risks of coronary artery disease, stroke and type 2 diabetes mellitus increase with increments in **BMI** (WHO, 2016). The increase in **BMI** also enlarges the risk of several types of cancer and mortality rates (GBD, 2015, WHO, 2018). **OBE** is considered a chronic multifactorial disease and, in children, approximately 95% of cases is the exogenous type. Exogenous **OBE** is a result of the interaction among genetics, behavioral (low level of physical activity, sedentarism and inadequate sleep), environmental and dietary factors (WHO, 2016; Kapedani & Mema, 2022). Children with **OVW** and **OBE** tend to remain obese in adulthood, and are more prone to develop **NCCD**, such as diabetes mellitus and cardiovascular diseases (Sahoo *et al*., 2015). Childhood **OVW** and **OBE** are associated to a greater morbidity in adulthood, though **OVW** and **OBE** are not strong predictors of these problems in the long term. However, besides the increase in future risks, obese children may experience breathing difficulties, increased risk of fractures, early markers of cardiovascular diseases and psychological impairments (WHO, 2018).

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Global prevalence of **OBE** in children and adolescents has increased almost tenfold in the past four decades, from 0.7% in 1975 to 5.6% in 2016 among girls, and from 0.9% to 7.8% among boys. They are 75 million girls and 117 million boys worldwide with **OVW** or **OBE**, resulting in an annual increase around 0.12 percentage point (%p) among girls and 0,17%p among boys (Ng et al., 2014, NCD-Risk, 2017).

In Brazil, secular trends of **NS** of children aged 5 to 9 years old was assessed by national inquiries in 1974-1975 (the National Family Expense Study - ENDEF), in 1989 (National Research on Health and Nutrition - PNSN), and, in 2008-2009, by the Family Budget research (POF) (IBGE, 2010). From 1974-1975 to 2008-2009, the prevalence of **OVW** went from 8.6% to 32.0% among girls, and from 10.9% to 34.8% among boys from 5 to 9 years old, indicating increases of 0.70%p per year in girls and boys. As for **OBE**, prevalence went from 1.8% to 11.8% and from 2.9% to 16.6%, respectively, resulting in increases of 0.29%p / year (girls) and 0.40%p /year (boys) (IBGE, 2010). **PF** refers to the set of characteristics related to the ability to perform physical activity, with stamina and liveliness, without excessive fatigue. It can be divided into health-related physical fitness (**HRPF**) and sports-related physical fitness (**SRPF**). **HRPF** includes adequate body composition, cardiorespiratory fitness, muscle strength and endurance, and flexibility (Corbin *et al*.,2000). These components are related to health and prevention of **NCCD**. **SRPF** includes essential components for competitive success, such as agility, speed, coordination, dexterity and reaction time, in addition to those related to **HRPF** (Corbin *et al*., 2000). Children's **PF** level has aroused much concern worldwide, due to the secular trends in decline, especially in cardiorespiratory fitness (Tomkinson *et al.,* 2003, Jürimäe *et al*., 2007, Tomkinson e Olds, 2007, Dos Santos *et al.*, 2015, Tomkinson *et al*., 2017). In Australasia, a study with 161.419 children and adolescents from 6 to 17 years old revealed that, in general, performance in cardiorespiratory fitness tests declined sharply between 1961 and 2002, 0,24p% per year (Tomkinson e Olds, 2007). In Estonia and Lithuania (Jürimäe *et al*., 2007), authors evaluated 12.226 children and adolescents and found that, between 1992 and 2002, cardiorespiratory fitness declined 0.04%p/year (Estonia) and 0.86%p/year (Lithuania). In Korea, Tomkinson *et al*. (2007), consulting the largest database of **PF** test results in the world, with 22,127,265 children and adolescents, observed a decline in aerobic fitness tests of 0.80%p/year from 1984 to 2000. In Mozambique (Dos Santos *et al.*, 2015), secular trends in **PF** levels of 3.851 subjects (1.791 boys and 2.060 girls) aged between 8 and 15 years, were worse in terms of flexibility, speed, agility and cardiorespiratory fitness.

Information on **PF** in Brazil is relatively scarce. In a review study, Tomkinson et al. (2017) showed data on cardiorespiratory fitness of 965,264 children and adolescents from 19 countries. In Brazil, there was an improvement of 0.13%p/year from 1981 to 2000 and 0.34%p/year from 2000 to 2014.

Recently, Gaya et al. (2020), released data from 2008 and 2014 from the Sport Brazil Project (PROESP-BR). Unhealthy results regarding flexibility and cardiorespiratory fitness have increased. Among girls and boys, respectively, flexibility worsened 2.42%p/year and 0.53%p/year, and cardiorespiratory fitness decreased 5.55%p/year and 4.65%p/year. At the same time, the prevalence of excessive weight (**EW** = **OVW** + **OBE**) went from 18.9% to 23.7%, an increase of 0.8%p/year.

Due to the lack of information on secular trends related to body composition and PF of children aged 6 to 10 years old in Brazil, and due to the discrepancy in this type of information, the present study sought to assess the secular trends in physical fitness (body composition, fitness cardiorespiratory and agility) of children between 6 and 10 years old from a private school in the south zone of the city of Sao Paulo. Our hypothesis was that between 2006 and 2016 there was a tendency for worse results.

Methods

This was a cross-sectional study. Anthropometric measures (weight, height, triceps and subscapular skinfolds), agility and cardiorespiratory fitness tests were conducted. In 2006 and in 2016, in the first day of testing, birth dates and anthropometric measures of weight and height were registered. After that, children were enrolled in recreational activities. In the second day, triceps and subscapular skinfolds were measured, and then children participated in games. In the third day, agility (shuttle-run, 4 x 9,15m) and cardiorespiratory fitness tests were conducted, and after testing children participated in recreational activities.

Participants

In 2006 and in 2016, 339 and 610 children aged 6 to 10 years old were assessed in a private school in the south zone of the city of Sao Paulo. The school administration and its pedagogical guidance received letters explaining the purpose and procedures of the study, which was carried out after the approval of local Research Ethics Committee (protocol nº 14/2006). All procedures were in accordance with the Declaration of Helsinki (www.wma.net) and Resolution 466/12 of the National Health Council (Brazil). Parents or legal guardians of the children were informed in detail about all procedures, that, incidentally, were a regular part of the school's pedagogical proposal for Physical Education. Written informed consents were sent to families, and even after their consent, the children who declined participation on the days of testing were respected without constraint.

Procedures

Quantitative variables in this study included age (years), height (cm), weight (kg), BMI (kg/m^2), triceps (TR) and subscapular (SE) skinfolds, agility (shuttle-run test) and 1,000m walk/run. Qualitative variables included categories related to anthropometry (height: low, adequate and high; weight: low, adequate and high; BMI: low, eutrophic, overweight and obesity; TR and SE: thinness, adequate adiposity, excessive adiposity and obesity); agility and cardiorespiratory fitness (inadequate and adequate results in relation to predicted values). The relative differences between the results obtained by children in 2006 and 2016 divided by 10 years, indicated the secular trend.

Anthropometry and body composition

Height (cm) was measured using an appropriate stadiometer, with fixed base and movable cursor, with precision of 0.1cm. The subject was put in orthostatic position, feet bare and joined, with back against the stadiometer ruler, heels, hips, shoulder girdle and occipital region in contact with the stadiometer. Subject's head was positioned according to the Frankfurt plan, with zygomatic arches parallel to the ground. After deep and sustained inspiration, height was registered (MATSUDO, et al., 2005). Body weight (kg) was obtained once, with the child in orthostatic position, feet slightly apart, wearing T-shirt, shorts or breeches and barefoot, on a previously calibrated digital scale (Filizola® Personal Life model) with precision of 0.1kg (MATSUDO, et al., 2005). Z scores for height for age (H/A) and body weight for age (W/A) were calculated by subtracting height and weight from the respective population medians for the age group, dividing the result by the population standard deviation. Values obtained were classified according to the World Health Organization (WHO, 2007): Z1 score <–1.881: low, Z2 score ≥ – 1.881 and ≤1.881: adequate, and Z3 score> 1.881: high.

BMI was calculated as follows: BMI (kg/m^2) = weight ÷ height ÷ height x 10,000. Z scores were calculated, and four categories were established: low weight for height: Z <–1.64, eutrophic: Z ≥ –1.64 to Z <1.04, overweight: Z ≥ 1.04, and obesity: Z ≥ 1.64 (WHO, 2007).

Relative body adiposity (%F) was determined by the equations of Slaughter et al. (1988), from triceps and subscapular skinfolds. Skinfolds were measured three times, and the median value was used for the calculations. The Slim Guide caliper (Harpenden model) was used, in the right hemisphere of the body (MATSUDO, et al., 2005). TR skinfold was measured with the child standing, body weight equally distributed on both feet, arms relaxed along the body, on the back side of the arm, in the mean distance between the lateral edge of the acromion and the bottom edge of the olecranon, following the longitudinal axis of the arm. SE skinfold was measured obliquely to the longitudinal axis of the body, following the orientation of the ribs, 2cm below the lower angle of the scapula. The equations for the estimation of %F were as follows:

1) White and black girls: if TR + SE < 35mm, %F = 1,33 x (TR + SE) – 0,013 x (TR + SE)^2 – 2,5; if TR + SE ≥ 35mm, %F = 0,546 x (TR + SE) + 9,7.

2) White boys: if TR + SE < 35mm, %F = 1,21 x (TR + SE) – 0,008 x (TR + SE)^2 – 1,7; if TR + SE ≥ 35mm, %F = 0,783 x (TR + SE) + 1,6.

3) Black boys: if TR + SE < 35mm, %F = 1,21 x (TR + SE) – 0,008 x (TR + SE)^2 – 1,7; if TR + SE ≥ 35mm, %F = 0,783 x (TR + SE) + 3,2.

Based on %F, body fat mass (FM = %F x BW ÷ 100) and lean mass (M = BW - FW) were calculated (where BW = body weight and FW = fat weight).

Additionally, results related to TR skinfold were analyzed according to the criteria disclosed by the "National Health and Nutrition Examination Survey I" (NHANESI), by Must, Dallal and Dietz (1991), for children from 6 years old onwards, summarized in **Chart 1**.

Chart 1: Cut-off values of triceps skinfold (TR, mm) of girls and boys aged 6-10 years old, regarding percentiles 5 (THI), 5 to 85 (ADE), 85 (EXC) and 95 (OBE).

Age (years)	**Girls**				**Boys**			
	THI	**ADE**	**EXC**	**OBE**	**THI**	**ADE**	**EXC**	**OBE**
6	<6.00	<13.44	<15.57	≥15.57	<5.04	<11.10	<14.12	≥14.12
7	<6.24	<14.94	<17.89	≥17.89	<5.01	<12.38	<15.61	≥15.61
8	<6.47	<16.41	<20.18	≥20.18	<4.96	<13.66	<17.18	≥17.18
9	<6.71	<17.85	<22.47	≥22.47	<4.91	<14.93	<18.81	≥18.81
10	<6.95	<19.01	<24.38	≥24.38	<4.84	<16.02	<20.68	≥20.68

Source: NHANESI, Must, Dallal and Dietz (1991). **THI**: thinness, **ADE**: adequate, **EXC**: excessive adiposity, **OBE**: obesity.

Physical fitness

Agility (S-R) was measured by the shuttle run test (4 x 9.15m). Each participant performed the test three times, covering the distance of 9.15m four times, alternately taking and leaving two pieces of wood with 5 x 5 x 10cm (height, width and length). The best result was considered in the analysis (MATSUDO, et al., 2005).

Cardiorespiratory fitness was determined using the 1,000m run / walk test. From the result in seconds, the maximum oxygen consumption (VO_2 max) was estimated using the following equation: VO_2 max (ml/kg/min) = (652.17 - time) ÷ 6.762 (Klissouras, 1973).

Statistical analysis

All analyzes were performed using SPSS version 24.0 and Graph Pad Prism version 6.0, both for Windows. Numerical variables were expressed as means ± SD, and categorical variables as frequencies and respective percentages. Children were grouped according to gender and year of assessment. Changes between 2006 and 2016, as well as between genders were analyzed using Student's t-test, and dichotomous associations using Pearson's correlation coefficients (r). The r values were interpreted as proposed by Cohen (1988 apud BATTERHAM; HOPKINS, 2006) and adapted by Mukaka (2012). Values of r ≤ 0.20 were considered **very**

weak, r ≤ 0.40 **weak**, ≤ 0.60 **moderate**, ≤ 0.80 **strong** and> 0.80 **very strong**. Associations between the different categories of BMI, %F, TR skinfold, physical fitness, the years 2006 and 2016, and genders, were assessed using the chi-square test. In all cases, the null hypothesis was rejected when p<0.05.

Results

Nine hundred and forty-nine schoolchildren aged 6 to 10 years were evaluated in 2006 (n=339 or 36%) and 2016 (n=610 or 64%), 438 (46%) girls (n=24 or 28% in 2006 and n=314 or 72% in 2016) and 511 (54%) boys (n=215 or 42% in 2006 and n=296 or 58% in 2016). **Table 1** summarizes anthropometric and body composition findings. Average age of girls and boys in 2016 was significantly higher than that of schoolchildren in 2006 (p<0.05), and the average age of boys was significantly lower than that of girls in 2016 (p<0.05). This was associated with the height of girls and boys (4.1 cm and 3.9 cm, respectively, p<0.05), increasing the Z scores by 0.24 and 0.26, respectively (p<0, 05). In 2006, the average height of girls did not differ from that of boys, but in 2016, boys were, on average, 1.8cm taller (p<0.05). When comparing the different prevalences of girls and boys in height categories, no significant differences were identified in 2006 and in 2016.

Mean body weight also increased (p<0.05) in both genders from 2006 to 2016 (3.1kg and 1.5kg), but these changes did not significantly affect Z scores, nor were any significant differences observed in the proportions of girls and boys regarding body weight categories. As for BMI, mean values, Z scores and the proportion of children per year and gender in the respective categories, did not significantly differ. Body adiposity was assessed by TR skinfold and %F. Both indicators did not undergo significant changes from 2006 to 2016 (**Table 1**). Only in 2016, boys exhibited lower mean values of the TR skinfold and %F than girls (p<0.05). Additionally, the proportion of boys in the obesity category was significantly higher (p<0.05), both in 2006 and in 2016. Body fat mass (FM) was significantly lower in boys in 2016 (p=0.044). Finally, in 2016, boys' lean mass (LM) was significantly higher than that observed in 2006 (p<0.05).

Table 1: Secular trends in anthropometry and body composition of schoolgirls and boys, aged 6 to 10 years old, after 10 years.

Variables	Girls		Boys	
Year	**2006**	**2016**	**2006**	**2016**
n	124	314	215	296
Age (years)	8.5 ± 1.2	9.1 ± 1.3*	8.3 ± 1.4	8.8 ± 1.2*#
Height (cm)	131.8 ± 9.4	135.9 ± 9.6*	130.2 ± 9.1	134.1 ± 9.3*#
Height (Z)	0.06 ± 1.21	0.30 ± 1.03*	-0.03 ± 0.99	0.23 ± 1.01*
Height classification				
Low	4 (3%)	4 (1%)	5 (2%)	5 (2%)
Adequate	117 (94%)	268 (92%)	201 (93%)	251 (94%)
High	3 (2%)	20 (7%)	9 (5%)	11 (4%)
Weight (kg)	31.2 ± 7.8	34.3 ± 9.7*	30.6 ± 8.4	33.1 ± 9.4*
Weight (Z)	0.54 ± 1.36	0.71 ± 1.45	0.67 ± 1.41	0.89 ± 1.57
Body weight classification				
Low	0 (0%)	0 (0%)	0 (0%)	1 (1%)
Adequate	106 (85%)	241 (82%)	177 (82%)	201 (75%)
High	18 (15%)	51 (18%)	38 (18%)	65 (24%)
BMI (kg/m²)	17.8 ± 3.3	18.3 ± 3.6	17.8 ± 3.1	18.1 ± 3.3
BMI (Z)	0.75 ± 1.51	0.82 ± 1.61	0.95 ± 1.61	1.02 ± 1.70
BMI classification				
Low	1 (1%)	0 (0%)	2 (1%)	1 (1%)
Euthrophic	77 (62%)	134 (62%)	185 (63%)	164 (61%)
Overweight	18 (14%)	28 (13%)	32 (11%)	30 (11%)
Obesity	28 (23%)	53 (25%)	73 (25%)	72 (27%)
TR (mm)	13.5 ± 5.7	14.4 ± 5.7	12.9 ± 6.4	12.3 ± 6.0#
Triceps (TR) skinfold classification				
Thinness	5 (4%)	6 (3%)	4 (2%)	3 (1%)
Adequate	84 (68%)	121 (66%)	142 (66%)	122 (67%)
Excessive	20 (16%)	35 (19%)	26 (12%)	25 (14%)
Obesity	15 (12%)	22 (12%)	43 (20%)	33 (18%)
%F	21.4 ± 7.8	23.1 ± 7.1	20.3 ± 10.2	20.2 ± 9.1#
%F (body adiposity) classification				
Thinness	25 (20%)	18 (10%)	15 (7%)	6 (3%)
Adequate	66 (53%)	103 (56%)	118 (55%)	103 (56%)
Excessive	13 (11%)	27 (15%)	31 (14%)	25 (14%)
Obesity	20 (16%)	36 (19%)	51 (24%)#	49 (27%)#
BF (kg)	7.2 ± 4.3	8.1 ± 5.1	7.0 ± 5.9	7.0 ± 5.3#
LM (kg)	24.0 ± 4.2	25.1 ± 5.7	23.7 ± 3.8	24.6 ± 4.4*

BMI: body mass index. **TR**: triceps skinfold. **%F**: body fat percentage. **LM**: lean mass. **BF**: body fat mass.
*P<0.05: statistically significant difference in the comparison between 2006 and 2016, within the same gender.
#P<0.05: statistically significant difference in the comparison between girls and boys, within the same year.

Table 2 summarizes findings of physical fitness. The agility of girls (0.56%p/year) and boys (0.54%p/year) worsened significantly in 10 years, and in both moments, it was significantly better in boys when compared to girls ($p<0.001$). Success rates (% of adequate results) dropped from 68% to 28% (girls) and from 73% to 26% (boys) ($p<0.001$), resulting in a reduction of 4.0 and 4.7%p/year, respectively (**Table 2**).

Boys' cardiorespiratory fitness (time to perform the 1,000m test) was better than that of girls in 2006 and 2016 ($p<0.001$). Among girls, no changes were observed in 10 years, but among boys, cardiorespiratory fitness worsened 0.83%p/year ($p<0.001$). Success rate among girls (% of adequate results), which was very low (14%) did not change in 10 years, but among boys it worsened significantly from 31% to 20% ($p<0.001$), decreasing 1.1%p/year (**Table 2**).

Table 2: Secular trends in physical fitness of schoolgirls and boys, aged 6 to 10 years old, after 10 years.

Variables	Girls		Boys	
Year	2006	2016	2006	2016
n	124	314	215	296
Agility (s)	12.50 ± 1.21	13.18 ± 1.27*	11.81 ± 1.27$^{\#}$	12.47 ± 1.27*$^{\#}$
Agility classification				
Inadequate	40 (32%)	226 (72%)	58 (27%)	189 (64%)
Adequate	84 (68%)	88 (28%)*	157 (73%)	107 (36%)*$^{\#}$
1,000m (s)	500 ± 104	499 ± 113	408 ± 73$^{\#}$	442 ± 95*$^{\#}$
VO_2 maximum	27.3 ± 8.1	24.6 ± 12.9*	36.6 ± 9.7$^{\#\#\#}$	31.6±12.6***$^{\#\#\#}$
Cardiorespiratory fitness classification				
Inadequate	94 (86%)	206 (80%)	119 (69%)$^{\#\#}$	210 (80%)*
Adequate	15 (14%)	52 (20%)	53 (31%)	54 (20%)*

Agility (shuttle-run test, S-R). **1,000** (s): walk / run 1,000m test. **Inadequate**: results below the expected mean for girls and boys. **Adequate**: results above the expected mean for girls and boys. *P<0.05 and ***P<0.001: statistically significant difference in the comparison between 2006 and 2016, within the same gender. $^{\#}$P<0.05, $^{\#\#}$P<0.01 and $^{\#\#\#}$P<0,001: statistically significant difference in the comparison between girls and boys, within the same year.

Table 3 shows the statistically significant correlation coefficients ($p<0.001$) among girls. **Age** was moderately and positively associated with height, body weight and LM, but weakly and inversely associated with agility (S-R). Age explained (r^2) 49% of the variability in height results, 25% in relation to body weight, 36% of LM and 15% of S-R. **Height** was strongly and positively associated with body weight, weakly associated with TR skinfold, moderately associated with %F and very strongly associated with LM, and explained 55% of the variation in weight results, 77% of LM, 18% of %F and 14% of TR skinfold. As expected, body **weight** was very strongly associated with BMI, TR skinfold, %F and LM, and explained, respectively, 71%, 56%, 62% and 88% of the variability of their results.

BMI correlated strongly with TR skinfold, %F and LM, and explained, respectively, 58%, 61% and 52% the variability of their results. **TR** skinfold was moderately and positively associated with LM and the time to complete the 1,000m test, and inversely associated with VO_2 max, and explained, respectively, 28%, 17% and 18% the variability of these results. **Cardiorespiratory fitness** (VO_2 max) moderately and inversely correlated with adiposity (TR: r^2 = 18% and %F: r^2 = 16%).

Table 3: Correlation matrix between body composition and physical fitness variables among girls.

Variables	1	2	3	4	5	6	7	8
1. Age (years)	-							
2. Height (cm)	0.70	-						
3. Weight (kg)	0.50	0.74	-					
4. BMI (kg/m^2)			0.84	-				
5. TR (mm)		0.38	0.75	0.76	-			
6. %F		0.42	0.79	0.78	0.97	-		
7. LM (kg)	0.60	0.80	0.94	0.72	0.53	0.56	-	
8. S-R (s)	-0.36							-
9. 1,000m (s)					0.41	0.39		
10. VO_2 max					-0.42	-0.40		

BMI: body mass index (kg/m^2). **TR**: triceps skinfold (mm). **%F**: body fat percentage. **LM**: lean mass (kg). **S-R**: time to perform shuttle-run agility test 4 x 9,15 m. **1,000m**: time, in seconds, to perform the walk / run 1,000 m test. **VO_2 max**: maximum oxygen consumption estimated by 1,000 m test (ml/kg/min). All r coefficients are significant (P<0.001).

Table 4 summarizes the correlation coefficients among boys. **Age** correlated strongly with height, moderately with body weight, strongly with LM, and weakly and inversely with agility (S-R). Determination coefficients (r^2) were, respectively, 58%, 31%, 42% and 14%. **Height** was strongly correlated with body weight, moderately with BMI, TR skinfold and %F, and very strongly correlated with LM. The r^2 were 62%, 19%, 19%, 21% and 74%, respectively. Body **weight** was very strongly associated with BMI, TR skinfold, %F and LM, and r^2 were 79%, 69%, 72% and 71%, respectively. **BMI** correlated very strongly with TR skinfold and %F, strongly with LM, weakly with the time to perform the 1,000m test and weakly and inversely with VO_2 max. The r^2 were: 81%, 83%, 36%, 15% e 15%, respectively. **TR** skinfold was moderately and positively associated with LM, time to complete the 1,000m test, and inversely associated with VO_2 max. The r^2 were: 21%, 22% and 22%, respectively. **Agility** (S-R) was moderately and positively correlated with the time to perform the 1,000m test and inversely correlated with VO_2 max (r^2 = 19% and 19%). **Cardiorespiratory fitness** (VO_2 max) correlated weakly and inversely with BMI (r^2 = 15%) and moderately and inversely with adiposity (TR: r^2 = 22%, %F: r^2 = 23%) and agility (r^2 = 19%).

Table 4: Correlation matrix between body composition and physical fitness variables among boys.

Variables	1	2	3	4	5	6	7	8
1. Age (years)	-							
2. Height (cm)	0.76	-						
3. Weight (kg)	0.56	0.79	-					
4. BMI (kg/m^2)		0.44	0.89	-				
5. TR (mm)		0.44	0.83	0.90	-			
6. %F		0.46	0.85	0.91	0.96	-		
7. LM (kg)	0.65	0.86	0.84	0.60	0.46	0.44	-	
8. S-R (s)	-0.38							-
9. 1,000m (s)				0.39	0.47	0.48		0.43
10. VO_2 max				-0.39	-0.47	-0.48		-0.43

BMI: body mass index (kg/m^2). **TR**: triceps skinfold (mm). **%F**: body fat percentage. **LM**: lean mass (kg). **S-R**: time to perform shuttle-run agility test 4 x 9,15 m. **1,000m**: time, in seconds, to perform the walk / run 1,000 m test. **VO_2 max**: maximum oxygen consumption estimated by 1,000 m test (ml/kg/min). All r coefficients are significant (P<0.001).

Discussion

The main findings of the present study confirm international (Tomkinson et al., 2017, Tomkinson and Timothy, 2007, Tomkinson et al., 2003) and national data (Gaya et al., 2020), indicating that, in the period of 10 years, despite no statistically significant changes in **BMI** and **%F**, there was a decline in **HRPF** and **SRPF**, as also previously hypothesized. The moderate and inverse correlations between cardiorespiratory fitness and body adiposity confirm the negative impact of **OVW** and **OBE** on **PF**, especially aerobic. This was expected, as the energy expenditure is greater to move a body with higher fat mass, negatively affecting performance in fitness tests. The increase in height between 3.9cm (girls) and 4.1cm (boys) is similar to other study (Albon et al., 2008), but, in the present study, it can be attributed to the higher average age of the students.

The decline in aerobic fitness has already been observed by several studies, with different populations of children and adolescents. Tomkinson et al. (2003) reviewed the subject and noticed a 0.42%p decline in cardiorespiratory fitness in 11 countries over a 20-year period. Subsequently, Tomkinson et al. (2007) studied data of more than 22 million children and adolescents aged 6 to 18 years in South Korea and observed decline in aerobic fitness of 0.26%p/year from 1968 to 1984 and 0.80%p/year from 1984 to 2000, revealing intensification of losses. Authors also reviewed the subject and identified declines ranging from 0.10%p/year in Northern Ireland to 1.83%p/year in New Zealand, in the 14 related countries, with an average decline of 1.7%p/year among children aged 9 to 12 years old, and 0.3%p/year among adolescents aged 13 to 17 years. More recently, Tomkinson et al. (2017) reviewed 137 studies from countries with high and medium income per capita and confirmed previous findings of decline in cardiorespiratory fitness of 0.22%p/year over 33 years. These authors provided evidence that countries with lower income per capita exhibited more pronounced declines in cardiorespiratory fitness.

Tambalis et al. (2011) evaluated data of 651,582 children aged 8 to 9 years old in Greece, in 1997 and in 2007, and found a 50% increase in the prevalence of obesity with a concomitant decrease of 4.9% (boys) and 4.4% (girls) in aerobic fitness. An association between increased rates of **OVW** and **OBE** and a trend of secular decline in cardiorespiratory fitness was also verified by Huotari et al. (2010), in Finland. These authors observed decline in cardiorespiratory fitness of 0.40%p/year in boys and 0.24%p/year in girls. BMI explained 12% (boys) and 17% (girls) of the declines in cardiorespiratory fitness. They also noticed that the low level of leisure-time physical activity explained the decline in physical fitness.

Venckunas et al. (2017) also verified declines in PF of schoolchildren aged 11 to 18, over 20 years, specifically regarding flexibility, strength of upper limbs, potency of lower limbs and cardiorespiratory fitness. These authors studied 16,199 children and adolescents tested on the Eurofit test battery. They associated these results with increases in BMI and TV time, and decline in physical activity levels. Declines in muscle strength and power were also observed by Moliner-Urdiales et al. (2010). Dos Santos et al. (2015) assessed 3,851 children and adolescents in Mozambique, aged 8 to 15, at three different points: 1992, 1999 and 2012. Children in 1992 were more flexible, faster and more agile than the ones in 2012. Isometric handgrip strength of boys increased from 1992 to 2012, while among girls it worsened. Cardiorespiratory fitness worsened between 1992 and 1999 and between 1999 and 2012. Albon et al. (2008) studied 3,306 children and adolescents aged 10 to 14 years old, in 1991 and 2003. The authors noticed an increase of 0.6%p/year and 0.5%p/year in the BMI of boys and girls, respectively, associated with a decline in cardiorespiratory fitness of 1.5%p/year and 1.7%p/year, respectively. This decline also occurred in agility (0.2%p/year and 0.4%p/year) and in lower limb power (0.3%p/year and 0.2%p/year).

In Brazil, Gaya et al. (2020) found that between the years 2008 and 2014, there was an increase in the prevalence of **EW** (**OVW** + **OBE**) of 0.8%p/year, and results of flexibility also worsened (girls: 2.42%p/year and boys: 0.53p%p/year) as well as cardiorespiratory fitness (girls: 5.55%p/year and boys: 4.65%p/year).

Matton et al. (2007) carried out an interesting study with male (in 1969 to 1974, n=11,899) and female adolescents (1979 to 1980, n=4,899) and both genders in 2005 (n=3,201) and, additionally, 55 pairs of fathers and sons and 62 pairs of mothers and daughters were analyzed. In addition to the secular increase in body weight, BMI, adiposity and the trunk-extremity index, they observed decline in several PF tests (flexibility, strength and speed of the lower limbs). When comparing fathers / mothers and sons / daughters, maturity was advanced only in sons in relation to fathers (not in daughters/mothers. These changes were not related to the practice of physical activities. Smpokos et al. (2012) evaluated 967 children aged 5.9 to 7.8 years in 1992/1993 and in 2006/2007, in Greece. As opposed to the increase in time spent watching TV, there was an increase in all physical fitness tests, associated with an increase in the time spent in moderate to vigorous physical activities.

This study has some limitations, mainly due to its transversal nature. Mean age of boys and girls in 2006 and 2016 were different, the second sample being older. However, it would be expected that older children exhibited better physical fitness results due to their physical maturation, suggesting that the observed decline might have been slightly higher among children of the same age.

Conclusion

Results of the present study indicate that, although the prevalence of overweight, excessive adiposity and obesity have statistically not changed along 10 years, physical fitness of children has worsened. Body weight and adiposity were inversely associated to physical fitness, confirming the negative impact of excessive body weight on performance and, certainly, in health.

Results support recent national and international data and reinforce the practical application of our data: the need for effective measures to face these declines as early as in childhood. Parents, teachers and health professionals must encourage a healthy lifestyle in children, especially concerning eating habits and an active behavior in school, at home and in leisure time, as sedentary habits directly affect children's health and will certainly impact later adulthood of these children. We suggest that future studies focus on identifying changes in lifestyle over time that may be related to the declines in physical fitness observed herein.

No conflict of interest.

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