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SECULAR TRENDS IN THE PHYSICAL FITNESS OF BRAZILIAN YOUTH: EVIDENCE THAT FITNESS IS DECLINING FOR THE MAJORITY BUT NOT FOR A FIT MINORITY

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ABSTRACT

Background: There has been a decline in children's physical fitness in recent decades. Such concerns are largely based on evidence from North America, Europe and Asia. The current study describes the secular trend and variation (spread) in the physical fitness scores of young Brazilians from 2005 to 2022.

Methods: This study is a repeated, cross-sectional surveillance study (1999-2022). Children and adolescents (n=65139; boys =36539) participated between 2005 and 2022. In each cohort six physical fitness tests were conducted: 1) 20-m sprint speed ($m.s^{-1}$), 2) cardio-respiratory 6-min run test ($m.min^{-1}$), 3) abdominal-strength test (sit-ups per min), 4) horizontal-jump test (cm), 5) the agility test ($m.s^{-1}$), and 6) the medicine ball throw test (cm). Means and distributional characteristics of the population were assessed using ANOVA, ANCOVA adopting BMI as the body-size covariate, Levene's test of equality-of-error variances, and Box and whisker plots.

Results: ANOVAs and ANCOVA's identified significant declines in physical fitness over time/year in 5 of the 6 physical fitness variables (e.g., 20-m sprint speed slope B =-0.018 ($m.s^{-1}.yr^{-1}$); 95% CI -0.019 to -0.017; P<0.001), the only exception being the medicine ball throw test (cm). The Levene's test of equality-of-error variances also identified a systematic increase in the *variances*/*standard deviations* over time/years.

Conclusions: Results provide powerful evidence that children and adolescents' physical fitness is declining, a trend that is also diverging asymmetrically, becoming more extreme in more recent years. The 'fit' appear to be getting fitter, but the fitness of the 'less-fit' appears to be declining further. These results have important implications for sports medicine and government policy makers.

Key words: motor performance; exercise test; change; children; adolescents

1. Introduction

Physical fitness consists of multiple components that collectively reflect an individual's ability to perform physical activity[1]. The measurement of physical fitness on a large scale among children and adolescents is one of the priorities of research around the world[2] and higher levels of physical fitness during childhood and adolescence is associated with more positive health outcomes[3]. Consequently, improving children's physical fitness continues of be a public health priority. However, there remain concerns that children are not as fit as they previously were, with physical fitness in decline in more recent years[4–6].

Systematic reviews focusing on high-income and upper-middle-income countries evidence a historical decline in standing broad jump performance, a plateau or slight decline in sit-ups performance, and a slowing of the decline into a plateau in cardiorespiratory fitness[4–6]. Another systematic review from 16 low and high-income countries evidence that performance in endurance, strength, and flexibility has also decreased over time[7]. To date, there is little evidence examining temporal trends over periods more than 10 years in the physical fitness of children and adolescents in Brazil.

The suggested explanation for the decline in physical fitness is related in many studies to the potential changes in lifestyle in the last decades[8]. Cross-sectionally, sedentary behaviour studies indicate a general increase in children's screen time, mainly in smartphone use, independent of national income[9]. This behaviour in youth is also negatively correlated with physical fitness[10]. Additionally, evidence indicates either a decrease or a stabilization in the physical activity levels in this population (approximately 20% of young that meet the WHO PA recommendation globally)[11]. This is an important observation as, according to a recent longitudinal study[12], children and adolescents with low levels of physical activity are physically weak (muscular strength related). This is doubly important, as lower levels of strength during childhood may track into adolescence and adulthood resulting in poor levels of muscle strength and subsequent ill health during adulthood[12].

Even with strong evidence of a decline in physical fitness in different countries, the particularities of each location must be considered as fitness levels vary across countries[13]. Our study seeks to understand how physical fitness behaves longitudinally in Brazil, a low-middle-income country that in the last decade has hosted several mega sporting events. Although physical activity levels in Brazil follow the global trend in terms of lower levels of habitual physical activity[11], there is still a considerable percentage of young people who practice sports regularly (approximately 30-35% of adolescents practice sports more than 3 times a week)[14] which by its nature necessitates particularly high levels of physical activity. Despite this, fitness levels of Brazilian children and youth are described as low, compared to other countries[15]. Our hypothesis is that the distribution of most physical fitness test results is becoming more diverse in recent years. There may be a specific group of young people who do not show the same decline in physical fitness (athletes probably), which can be observed by monitoring indicators of variance/standard deviations over time. This is important as Dooley et al (2020)[16] recommended trends in measures of central tendancy (means, medians) be complemented by trends in measures of variability (SDs, CVs) and asymmetry (skewness), to identify whether the trends have been uniform or non-uniform across the distribution. There is some evidence that distributional variability substantially increased over time in Italian youth, with larger declines in endurance performance for children with low running speed compared to children with average or high running speed[17]. There have been some similar studies examining temporal trends in physical fitness for children and youth from New Zealand[18], Australia[19] and Hong Kong[20]. However, to date, studies examining temporal trends in physical fitness in children and youth from South America are lacking. Thus, the aim of this study is to describe the secular trend and variation (spread) in the physical fitness scores of young Brazilians from 2005 to 2022.

2. Methods

2.1. Study design and participants

This study is part of the Projeto Esporte Brasil (PROESP-Br), which is a repeated, cross-sectional surveillance study (1999-2022) designed to assess anthropometry, sports practice, and physical fitness levels of Brazilian children and adolescents through a standardized data collection protocol[21]. Ethics approval for this project was originally obtained from the Universidade Federal do Rio Grande do Sul, Brazil, under register number: 2008010. For this study, 570 research assistants (physical education teachers, sports coaches and strength and conditioning professionals) participated in data collection.

After registration, the volunteers received PROESP-Br guidelines[21] through an online multiplatform >https://www.ufrgs.br/proesp/<. Training for data collection was carried out through online video classes, one class for each test (about 5-8 minutes), in addition to complementary reading material. Video lessons were available full-time on the online multiplatform and a phone number was available (at the university) for specific questions. Initially, pilot studies were published in 2002 and 2005, but unfortunately, reliability values were not reported at that time[22,23].

Using non-random sampling methods, participants in all five regions of Brazil, including the Amazon region and native peoples (indigenous), were recruited in at least five cities in each region, considering the wide geographic distribution of Brazil. Among recruitment sites, primary and secondary schools account for more than 70% (distributed over the years between 63% - 75%), the rest of the sites are made up of public and private sports clubs, sports schools, social projects, and local cross-sectional research projects (linked to PROESP-Br). In all stages of the research, participants were invited to participate in the study, and written informed consent was obtained from parents or legal guardians, aware that they could give up for any reason, without consequences.

Participants were considered eligible for this study if they were aged between 6 and 17 years old, able to perform physical tests at maximum effort, and moderate to vigorous physical activities were not constrained by a pre-existing medical condition. Data were cleaned (removing typos and incongruent values), and available from 2005 to 2022. This time line was divided into three time/year sub-categories 2005-2009, 2010-2014 and 2015-2022 (2015-2020+). The number of participants boys (n=36539) and girls (n=28600) by age, sex and time/year are given in Table 1. This sample is distributed among the five regions of the country, including the Amazon region and native (indigenous) peoples, in addition to respecting the proportionality between rural and urban populations (supplementary figure 1).

>> Table 1 near here<<

2.2. Procedures

2.2.1 General procedures of data collection

The PROESP-Br guidelines[21] for assessment of fitness tests were followed for all schools and participants in the present study. These guidelines advise participants to wear light clothing and appropriate footwear for sports practice whenever possible (with the exception of anthropometry, where assessment takes place barefoot). Congruent with the PROESP-Br guidelines[21] the teacher performed a joint warm-up before each assessment section (there are prescribed warm up activities within the PROESP-Br guideline). Assessments were conducted with a maximum of 20 participants per section, and used four classes/sections to carry out the assessments: day 1) body mass measurements (weight); stature (height); arm-span, waist circumference, and the sit and reach test (not included in this study); day 2) Abdominal strength test and Cardio-respiratory 6-min run test; day 3) horizontal jump and 20-m speed test; and day 4) medicine ball throw and agility test.

Guidelines recommended that teachers should not perform assessments at very high or very low temperatures, but this was not controlled in this study. Another factor that could not be controlled was the type of test floor (but professors were encouraged to indicate the temperature). The guidelines were to conduct the fitness assessment in the school setting. As the majority of schools in Brazil do not have a sports hall/gymnasium, tests were performed on a concrete based court/playground space, as is common for fitness assessment and Physical Education in Brazil.

2.2.2 Physical fitness variables

20-m sprint speed test ($m.s^{-1}$)

For speed assessment, we used the 20-meters sprint test, as prior research identified this test as valid for screening low bone density in Brazilian children (ROC curves were 0.710 for boys, and 0.712 for girls)[24]. The researcher demarcates a 20-meter runway with three parallel lines on the ground as follows: the first (start line), the second, 20m away from the first (timeline) and the third line, marked by two meters from the second (finish line) to serve as a finishing reference for the student in an attempt to avoid deceleration before crossing the timeline. The appraiser must start the stopwatch when the participant takes the first step and touches the ground for the first time and the stopwatch will be stopped when the participant, crosses the second line (timeline). The 20 m sprint speed is recorded in metres per second to two decimal places.

Cardio-respiratory 6-min run test ($m.min^{-1}$)

For cardiorespiratory fitness we used the 6 Minutes' Walk/Running test, this test showed good validity criteria (r=0.704 from VO_{2max} data)[25] and was able to predict the VO_{2peak} of Brazilian adolescents[26]. The children were instructed that they should run as long as possible, avoiding speed spikes interspersed with long walks. During the test, the student was informed of the passage of time 2, 4 and 5 minutes and a signal indicated the end of the test. The child remained in the place where they finished until the distance covered was as recorded to the nearest whole meter. The measure is recorded in meters per minute (distance divided by 6 with no space after the comma.

Abdominal strength test (sit-ups per min)

For abdominal strength assessment we used the Sit-Ups in 1 minute, a test that can assess localized muscle resistance of the core. There is also some evidence that the test can be used to screen lower back pain in Brazilian adolescents[27]. The child was in a supine position, with knees bent at 45º and arms crossed over the chest. The evaluator, with his hands, held the child's ankles, fixing them to the ground. At the signal, the child started the trunk flexion movements until touching the elbows with the thighs, returning to the initial position. The child performed the most complete repetitions in 1 minute.

Horizontal jump test (cm)

We used the Horizontal Jump Test that has good criterion validity (R^2 = 0.829-0.864 for other lower body muscular-strength tests data) [28]. The child stands behind landmark 0, with feet parallel, slightly apart, knees semi-flexed, and trunk slightly forward. At the signal, the child jumps as far as possible, landing with both feet simultaneously. The jump distance was recorded from landmark 0 to the nearest heel. Two attempts were made with the best result recorded in centimetres.

Medicine ball throw test (cm)

For upper muscle power assessment, we used the 2kg Medicine Ball Throw Test, this test proved to be valid for screening low bone density in Brazilian children (ROC curves were 0.703 for boys, and 0.806 for girls)[24]. The child sits with knees extended, legs together and back fully supported by the wall. The child holds the medicine ball to their chest with elbows bent. At the evaluator's signal, the student throws the ball as far as possible, keeping their back against the wall. The pitch distance is recorded from point zero to the place where the ball first touched the ground. Two shots are taken, registering the best result for evaluation purposes, recorded in centimetres.

Agility test ($m.s^{-1}$)

For agility assessment, we used the 4-m square test, a field-based test with good criterion validity ($R^2 = 0.579 - 0.544$ with other agility and change-of-direction speed tests data)[29]. The researcher demarcates, with cones, a square with four meters on a side. At the evaluator's signal, the participant should move at full speed and touch the cone located in the diagonal corner of the square with one hand. Next, they run to touch the cone to their left (or right) and then moves to touch the cone diagonally. Finally, they run towards the last cone, which corresponds to the starting point (total distance 19.31 m). Two attempts were made, the shortest time being registered for evaluation purposes. The measurement of agility speed was recorded in metres per second (two places after the decimal point).

Body mass index (kg/m^2)

For the measurement of body mass, volunteers were instructed to use a portable scale with an accuracy of up to 500 grams. During the assessment, the children and adolescents remained standing. For height, a portable stadiometer or measuring tape with a precision of up to 2 mm was used. When the measuring tape was used (considering that it normally measures 150 centimetres in length) it was attached to the wall, 100 centimetres from the ground, extending it from bottom to top (in this case, the evaluator added 100 centimetres to the result measured by the measuring tape). For the calculation of the body mass index (BMI), after sending the data to the PROESP-Br website, BMI was calculated as weight (kg) divided by height (m^2). In some analyses, we used BMI as a covariate.

2.3 Statistical analyses

In order to identify any temporal trend in the six physical fitness variables over time/years (using 5-year grouping categories), we adjusted the fitness variables for differences in the confounding variables of sex and age. For this reason, all six physical fitness variables were analysed, initially using a three-way ANOVA (factors being sex, age and time/years) and subsequently, using a three-way ANCOVA adopting the same three factors but incorporating BMI as the body-size covariate. The statistical significance adopted was $p<0.05$. Data were assessed for accuracy using the usual diagnostic tests (Q-Q plots for normality and outliers, etc.) and all analyses were conducted using the statistical software SPSS version 28.

3. Results

All six three-way ANOVAs identified significant main effects of sex, age, and time/years, together with a consistent age-by-sex interaction (all P<0.001). Having controlled for sex and age, there is clear evidence of a monotonic decline in physical fitness over time/year in 5 of the 6 physical fitness variables; these being 1) 20 m sprint speed ($m.s^{-1}$), 2) cardio-respiratory 6 min run test ($m.min^{-1}$), 3) abdominal strength test (sit-ups per min), 4) horizontal-jump test (cm) and 5) the agility test ($m.s^{-1}$). In contrast, there was clear evidence of a monotonic increase in the medicine ball throw test (cm) performance over time/years, see Figures 1a, 1b, 1c, 1d, 1e, and 1f.

>> Figure 1 near here<<

We identified a significant increase in BMI over time/ years, also having controlled for sex and age, see Figure 2. The introduction of BMI as the covariate into the six ANCOVAs made a significant contribution to the prediction models (all P<0.001) but made only a relatively small increase in the explained variance (R^2) of the 6 FP variables, see Table 2.

>> Figure 2 near here<<

>>Table 2 near here<<

The introduction of BMI into the six physical fitness ANCOVAs had very little influence on the main effect ‘change over time/year’, see Figures 3a, 3b, 3c, 3d, 3e and 3f. Since the temporal trends in the six in physical fitness variables were all monotonic, see Figures 1a, 1b, 1c, 1d, 1e, 1f, and 3a, 3b, 3c, 3d, 3e and 3f, for comparative purposes, we were able to estimate the linear trends in all 6 fitness variables per year, using linear regression/ANCOVA (see Table 3). Effect sizes (Partial Eta Squared) of the slope parameters were also calulated and included in the table.

>> Table 3 near here<<

>>Figure 3 near here<<

Careful examination of the means and standard deviations of all six physical fitness variables by time/year (categories) revealed the systematic decline in the *means* of 5 physical fitness variables (see figures 1a, 1b, 1c, 1d, and 1e) but a systematic increase in the *standard deviations* over time/years, see Table 4, especially in the older children or adolescents. This can be clearly seen by observing the box and whisker plot (Figure 4) for speed in the 17-year-old boys. We also observed an asymmetry (a ***positive*** skewness) in 5 of the 6 fitness variables' residuals reported in Table 4, confirming that the more elite performers are less frequent within the population.

>>Table 4 near here<<

>>Figure 4 near here<<

4. Discussion

This study examined secular trends in physical fitness in Brazilian youth over more than 15 years. Examining secular trends in fitness parameters is a key step in targeting interventions for public health benefit and has implications for sports medicine practitioners. The results of the present study offer unique insight into the longitudinal changes in fitness in Brazil.

The results of the present study provide clear evidence that performance in most physical fitness tests have declined over the past 17 years. In five of the six physical fitness test (20-m sprint speed ($m.s^{-1}$), cardio-respiratory 6-min run test ($m.min^{-1}$), abdominal-strength test (sit-ups per min), horizontal-jump test (cm) and the agility test ($m.s^{-1}$)), the decline is significant and consistent with other studies[4–6]. The only exception was the medicine ball throw (cm) that increased significantly over these time/years. The reasons for this anomaly, in contrast to the other physical fitness tests employed in this study is unknown. It is also difficult to compare the results relating to medicine ball throw performance to prior studies, as no prior work examining secular trends in physical fitness appears to have examined measures of upper body power[16-18,20] despite the medicine ball throw test being clinically relevant as a marker of children's bone health[24].

These temporal trends might have been anticipated, given the significant rise in BMI over the current time span. The five physical fitness test that declined over time/years are weight/mass dependent (all 5 tests require the child to perform the test whilst carrying, limited by, their own body weight). The only test that did not require the child to perform the test whilst carrying, and hence limited by their own body weight, was the medicine ball shot (cm). In this case greater mass, especially if the excess mass was muscle mass, is likely to benefit performance, hence the increase in the children's shot performance over the 17-year time span. Indeed, when we incorporated BMI as a covariate into the analyses, the negative BMI covariates in the 5 weight-bearing physical fitness tests confirmed the detrimental effect of excess body mass, whilst the positive BMI covariate for the medicine ball shot confirmed the beneficial effect of excess body mass (see Table 2).

However, given the significant effect of incorporating BMI as a covariate into all 6 analyses, the change in the explained variance (R^2) was relatively small (0.3 to 3.9%). Indeed, the temporal trends in the 6 physical fitness tests remained almost unchanged, confirmed by comparing the changes over time/years in Figure 1 with Figure 3. Clearly, the increase in BMI is not the prime explanation for these temporal trends in physical fitness. The results of the present study in this respect are supportive of prior work on affluent English school children which reported 10-year declines in cardiorespiratory fitness which were independent of BMI[30]. As a consequence, it is important to explore what might influence these temporal declines in physical fitness if not an increase in BMI.

Although the trends in the means may be considered small it is still important to highlight where such trends exist (also clearly seen in Figures 1 and 3). By observing the distributional changes in our data, using the standard deviations as well as the means when observing the changes in physical fitness over time, we begin to obtain new insights into what might be causing the decline in children’s physical fitness over the past 17 years. Table 3 confirms that the standard deviations of all 6 physical fitness tests are systematically increasing over time. Despite a steady decline in 5 of the physical fitness tests, the distribution of the physical fitness scores is increasing/expanding. The results of the present study therefore demonstrate a divergence of physical fitness over time in Brazilian youth. The positively skewed asymmetric nature of the frequency distributions observed in five of the physical fitness measures also support the assertion that the fittest children, identified in these “long tails”, are relatively infrequent but nevertheless superior, fitter performers.

This confirms that a relatively small number of children’s physical fitness performances are still improving compared with previous age groups. In contrast, a greater number of less talented children’s physical fitness performances are under performing compared with previous age groups (see, for example Figure 4), leading to the observed temporal decline in physical fitness. The findings of the present study are important as we show that while for a large number of youths, there is a decline in physical fitness, there are also a group where physical fitness continues to improve. Similar conclusions have been drawn for cardiovascular endurance in Italian children and youth[17]. The present study is the first to demonstrate this in children and adolescents from Brazil.

The current study is not able to determine cause and effect but we might speculate that increases in Brazilian young people's sedentary behaviour, and decreases in habitual physical activity (simultaneous physical activity and sedentary behaviour trend: 2009:

56.4%; 95%CI 55.7–57.1; 2012: 53.7%; 95%CI 53.0–54.4; 2015: 51.9%; 95%CI 51.2–52.7)[31] as a consequence of lifestyle behaviours may result in declining physical fitness, as observed in the current cohort. In addition, recent evidence[14] has shown that even though Brazil has been the site of several mega-sport events (e.g. Olympic and Paralympic games Rio 2016), it has not translated into increased sports participation in children and adolescents. One of the key cited reasons for a decline in habitual activity in youth is cessation of participation in sporting activities[32], and one of the cited reasons as to why children and adolescents maintain levels of physical fitness and physical activity is sports participation[32,33].

Clearly, examining the underlying reasons for the divergence in physical fitness over time that we observe in the present study is needed. Changes in participation in organised sport by Brazilian children in youth may be one possible explanation. Where youth continue their participation in organised sport and physical activities, physical fitness is maintained or increases, but where youth do not continue their participation in organised sport and physical activities, physical fitness declines in those that may discontinue such involvement in organised activities. This suggestion is of course speculative and future work is needed to examine this issue in greater depth. Learning why the fit minority continue to maintain and improve their fitness is a key step to understand how to empower the less-fit majority to avoid what appears to be an inevitable decline in their physical fitness.

Finally, our study has strengths that deserve to be highlighted: 1) the representativeness of the sample, with more than 60000 participants, representing all five regions of Brazil. This sample includes minority ethnic groups such as natives (indigenous); 2) we assessed, in the same study, most of the physical capabilities that comprise physical fitness providing a holistic representation of physical fitness as a single construct. Understanding of trends in children's fitness in previous studies[18,19,20] is limited by only examining the means. To fully examine any trend in fitness both centrality and variability/symmetry need to be examined, as in the present study.

However, our results are not without some limitations: 1) although the sample is large, the Southeast and South regions of Brazil represent the largest number of participants in the sample, which may represent a tendency to characterize these areas more to the detriment of others; 2) The method of online training of evaluators was consistent, although no results on the reliability have been published; and 3) although the horizontal jump and agility tests used in the present study are widely employed in Brazil, criterion validity for the horizontal jump and agility tests in the current population are lacking and evidence linking abdominal/core endurance with musculoskeletal pain is unclear in the literature.

5. Perspective

Collectively, the results indicate that from 2005 to 2022 there was a decline in the physical fitness of Brazilian children and adolescents. BMI increased over time but did not significantly influence trends in physical fitness variables.

However, a more detailed approach revealed a systematic increase in standard deviations over time/years, especially in older children or adolescents, indicating a trend towards polarization of the results. This means that despite the decreasing average, there is a tendency for a select group of children and adolescents to be increasingly fit over time, as well as another group (probably very sedentary) to be less and less-fit over time.

The present study therefore highlights that while there is a decline in physical fitness for children over time, there is also a group of children that maintain their fitness. Understanding the most effective behaviour change strategies to incentivise those youth where fitness is declining is an important challenge for future research. Such a finding is key for public health in understanding current trends in physical fitness for this group of children and adolescents, that temporal trends in fitness performance do not represent a 'one size fits all', and different types of intervention strategies may be needed for children with different fitness profiles.

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Table 1. The number of participants by age, sex, and time/year.

	Boys				Girls			
Age	2005-2009	2010-2014	2015-2020+	Total	2005-2009	2010-2014	2015-2020+	Total
6	381	166	158	705	322	156	109	587
7	1096	357	302	1755	938	350	173	1461
8	1458	582	362	2402	1206	527	241	1974
9	1721	684	535	2940	1401	585	317	2303
10	2430	809	677	3916	2087	604	438	3129
11	3241	814	948	5003	2919	503	631	4053
12	3525	833	1048	5406	2948	521	811	4280
13	3543	852	1042	5437	2919	537	701	4157
14	2594	824	961	4379	1977	591	724	3292
15	920	643	804	2367	609	510	563	1682
16	309	518	690	1517	220	367	564	1151
17	56	283	373	712	54	180	297	531
	21274	7365	7900	36539	17600	5431	5569	28600

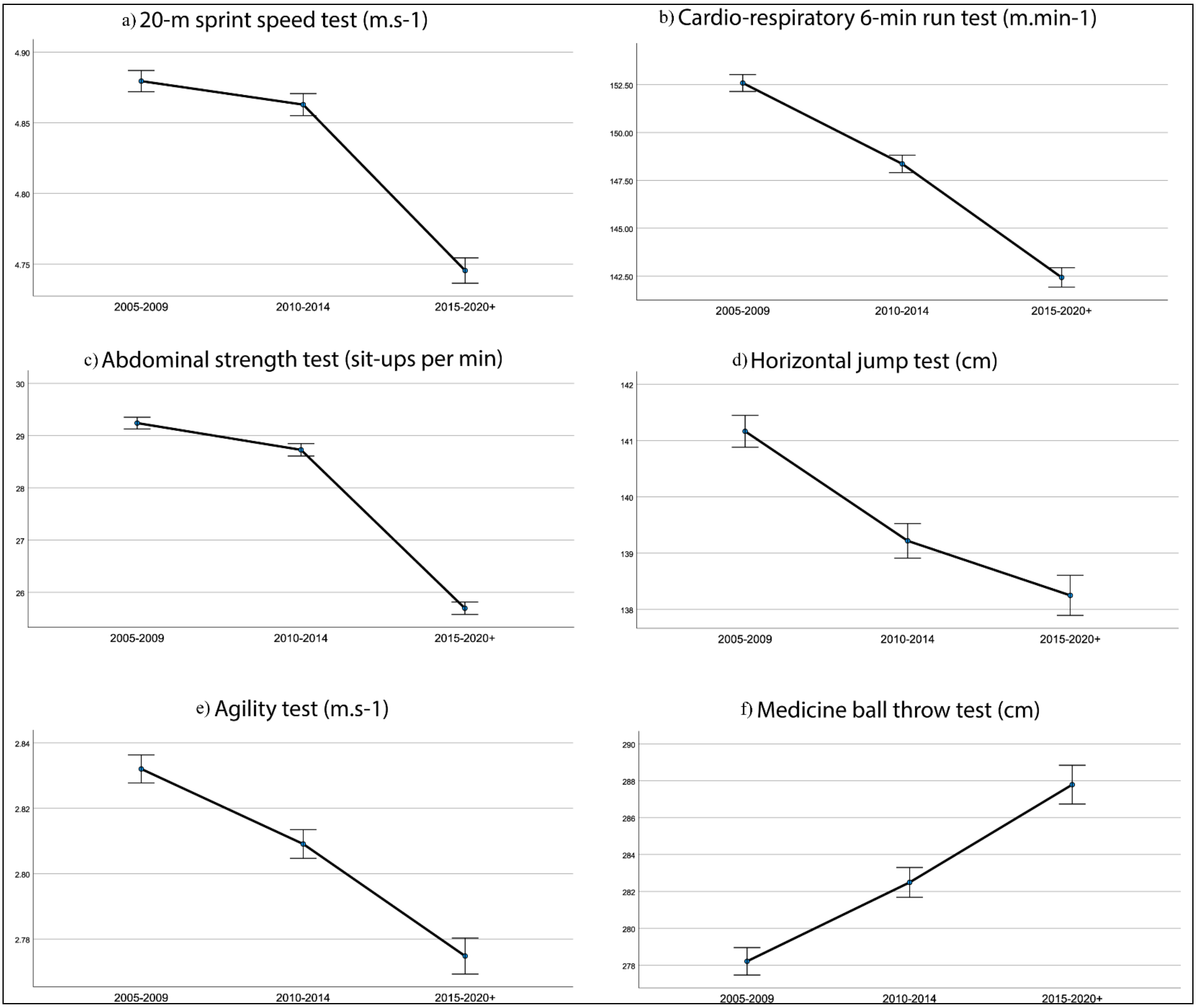

Figure 1. Means (±SE) for a) 20 m sprint speed (m.s^{-1}), b) cardio-respiratory 6 min run test (m.min^{-1}), c) abdominal strength test (sit-ups per min), d) horizontal-jump test (cm), e) the agility test (m.s^{-1}) and f) medicine ball throw test (cm) over time/years, having controlled for sex and age.

Error bars: +/- 1 SE; m.s-1: meters per second elevated at -1; m.min-1: meters per minute elevated at -1; cm: centimetres.

Figure 1a. Means (±SE) for 20 m sprint speed (m.s^{-1}) over time/years, having controlled for sex and age.

Figure 1b. Means (±SE) for cardio-respiratory 6 min run test (m.min^{-1}) over time/years, having controlled for sex and age.

Figure 1c. Means (±SE) for abdominal strength test (sit-ups per min) over time/years, having controlled for sex and age.

Figure 1d. Means (±SE) for horizontal-jump test (cm) over time/years, having controlled for sex and age.

Figure 1e. Means (±SE) for the agility test ($m.s^{-1}$) over time/years, having controlled for sex and age.

Figure 1f. Means (±SE) for the medicine ball throw test (cm) over time/years, having controlled for sex and age.

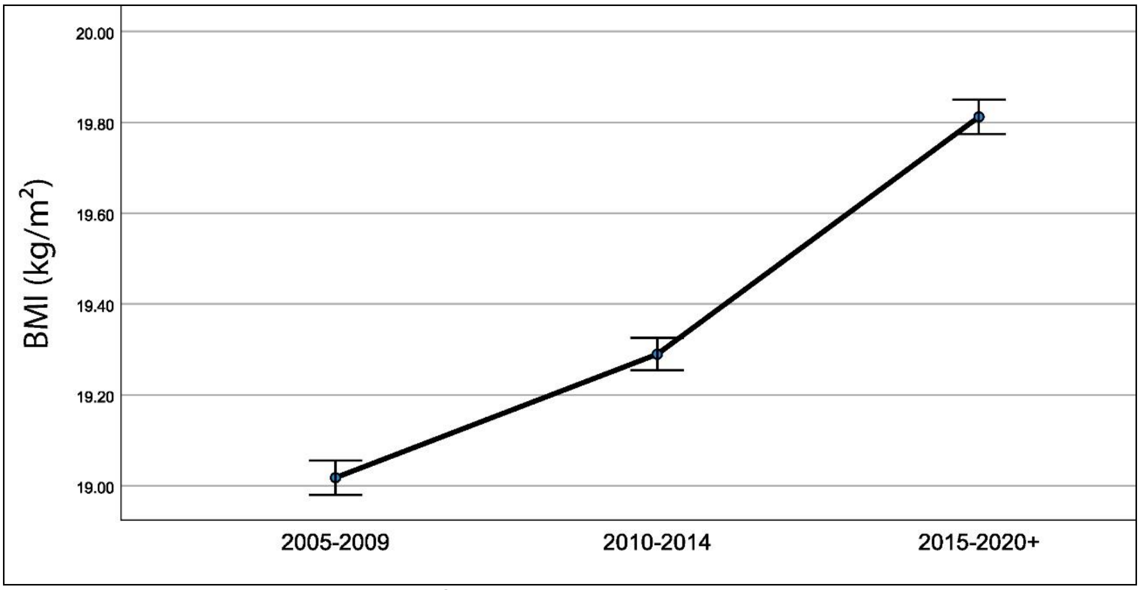

Figure 2. Mean BMI (±SE) in (kg.m^{-2}) over time/years, having controlled for sex and age.

Table 2. The explained variance (R^2) from the 3-way ANOVA's (factors being sex, age and time/years), 3-way ANCOVA's using BMI as the covariate, percentage difference and details of the fitted BMI covariate parameters.

	ANOVA	ANCOVA	diff					95% Confidence Interval	
Physical Fitness variables	R^2	R^2	%	BMI covariate	SEE	t	Sig.	Lower Bound	Upper Bound
Speed (m.s-1)	0.288	0.3	1.2	-0.026	0.001	-31.6	<0.001	-0.028	-0.025
CRF (m.min-1)	0.189	0.228	3.9	-2.147	0.044	-48.4	<0.001	-2.234	-2.060
Abdom Str (sit-ups)	0.153	0.17	1.7	-0.433	0.012	-35.4	<0.001	-0.457	-0.410
Horizontal Jump (cm)	0.376	0.397	2.1	-1.386	0.032	-43.1	<0.001	-1.449	-1.323
Agility (m.s-1)	0.256	0.259	0.3	-0.0071	0.0005	-15.0	<0.001	-0.008	-0.006
Med ball throw (cm)	0.558	0.585	2.7	5.009	0.083	60.5	<0.001	4.847	5.171

CRF: cardiorespiratory fitness; Abdom Str: abdominal strength; SEE=Standard Error of Estimate; t=t-score, diff=difference

Table 3. Linear regression trend/slope parameters, B (per year) of the 6 physical fitness variables plus the standardized effects sizes (Partial Eta Squared).

					95% Confidence Interval		
Physical Fitness variables	B	SEE	t	Sig.	Lower Bound	Upper Bound	Partial Eta Squared
Speed (m.s-1)	-0.018	0.001	-27.567	<0.001	-0.019	-0.017	0.014
CRF (m.min-1)	-0.800	0.036	-22.430	<0.001	-0.870	-0.730	0.010
Abdom Str (sit-ups)	-0.230	0.010	-24.195	<0.001	-0.249	-0.211	0.010
Horizontal Jump (cm)	-0.232	0.026	-8.964	<0.001	-0.283	-0.181	0.001
Agility (m.s-1)	-0.007	0.000	-19.597	<0.001	-0.008	-0.007	0.007
Med ball throw (cm)	0.814	0.069	11.838	<0.001	0.679	0.949	0.003

CRF: cardiorespiratory fitness; Abdom Str: abdominal strength; SEE=Standard Error of Estimate; t=t-score

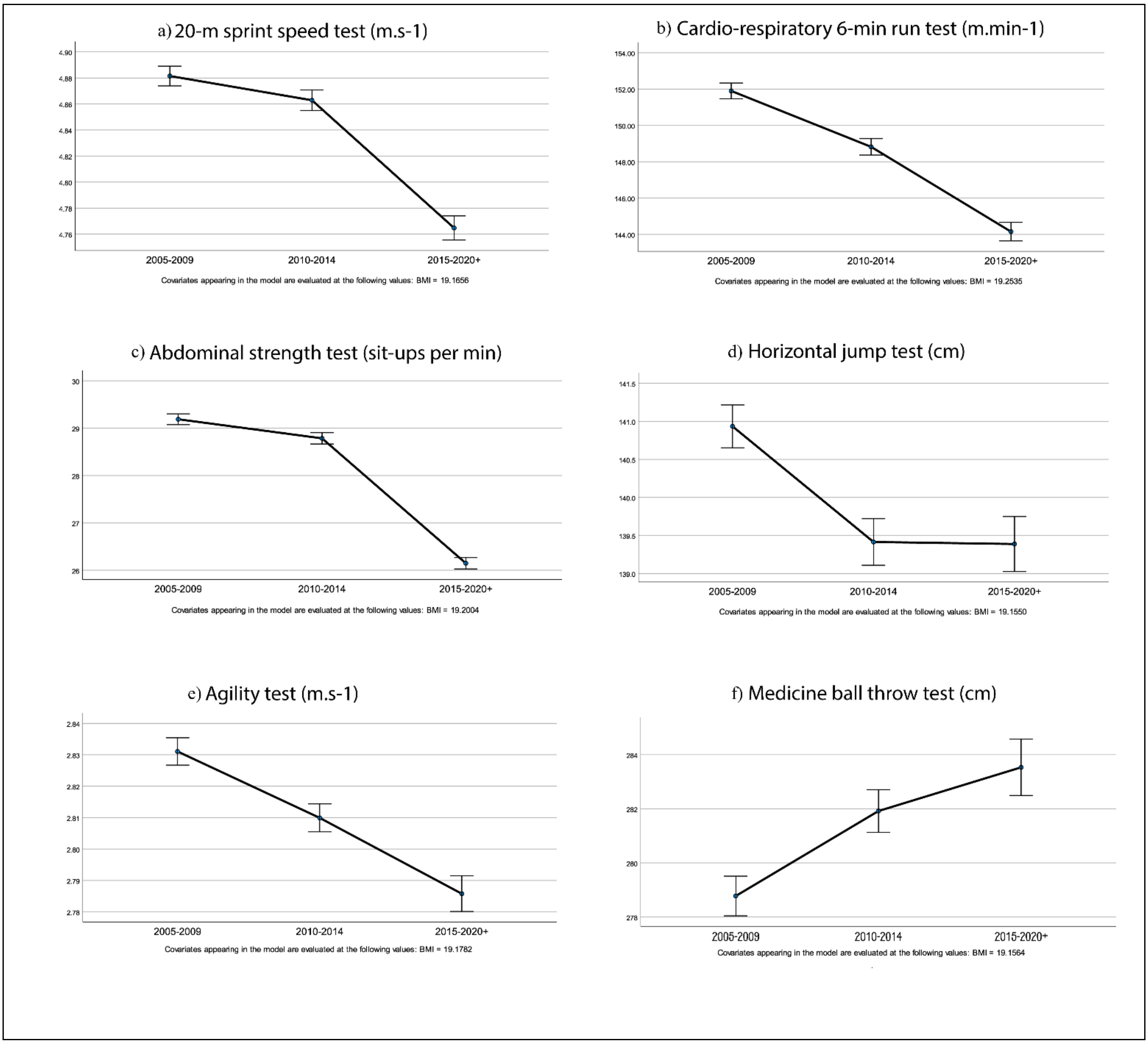

Figure 3. Means (±SE) for a) 20 m sprint speed (m.s^{-1}), b) cardio-respiratory 6 min run test (m.min^{-1}), c) abdominal strength test (sit-ups per min), d) horizontal-jump test (cm), e) the agility test (m.s^{-1}) and f) medicine ball throw test (cm) over time/years, having controlled for BMI (covariate), sex and age.
Error bars: +/- 1 SE; m.s-1: meters per second elevated at -1; m.min-1: meters per second elevated at -1; cm: centimetres.

Figure 3a. Means (±SE) for 20 m sprint speed (m.s^{-1}) over time/years, having controlled for BMI (covariate), sex and age.

Figure 3b. Means (±SE) for cardio-respiratory 6 min run test (m.min^{-1}) over time/years, having controlled for BMI (covariate), sex and age.

Figure 3c. Means (±SE) for abdominal strength test (sit-ups per min) over time/years, having controlled for BMI (covariate), sex and age.

Figure 3d. Means (±SE) for horizontal-jump test (cm) over time/years, having controlled for BMI (covariate), sex and age.

Figure 3e. Means (±SE) for the agility test ($m.s^{-1}$) over time/years, having controlled for BMI (covariate), sex and age.

Figure 3f. Means (±SE) for the medicine ball throw test (cm) over time/years, having controlled for BMI (covariate), sex and age.

Table 4. The standard deviations by time/year, Levene's Equality of Error Variances test plus the skewness (SEE) of residuals saved from the ANOVAs reported in Table 2

Years	2005-2009	2010-2014	2015-2020+	Levene's test	Sig.	Skewness	SEE
Speed (m.s-1)	0.61	0.70	0.77	316.0	<0.001	-0.145	0.011
CRF (m.min-1)	33.49	35.56	37.89	19.7	<0.001	0.620	0.011
Abdom Str (sit-ups)	10.07	9.92	11.65	96.6	<0.001	0.114	0.010
Horizontal Jump (cm)	25.23	28.77	29.61	159.6	<0.001	0.092	0.010
Agility (m.s-1)	0.35	0.38	0.45	275.4	<0.001	0.392	0.011
Med ball throw (cm)	64.79	71.42	79.68	190.4	<0.001	0.043	0.010

CRF: cardiorespiratory fitness; Abdom Str: abdominal strength; Levene's Test = Test of Equality of Error Variances

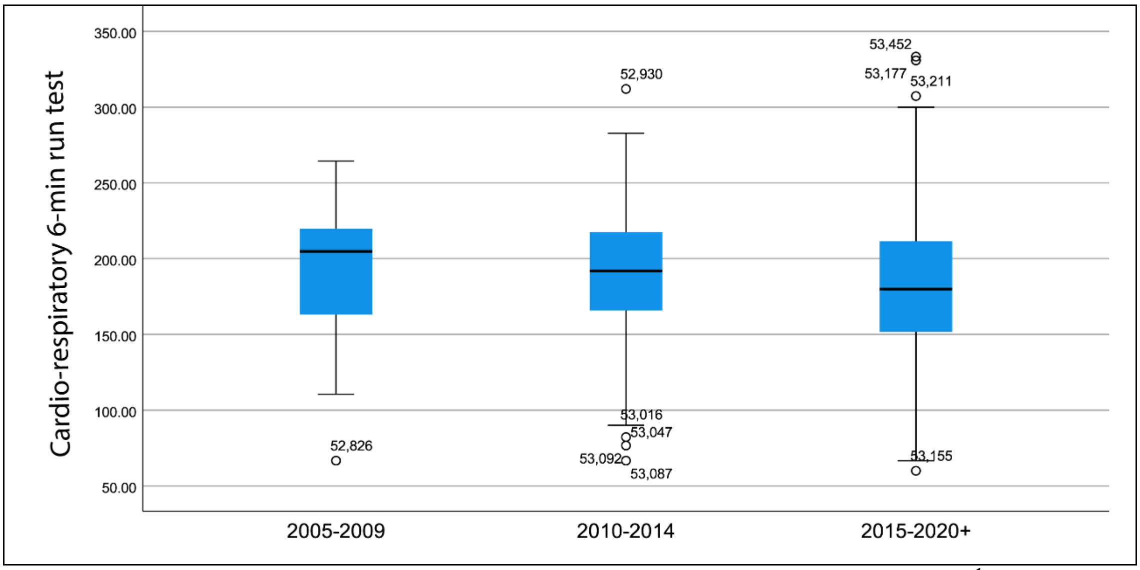

Figure 4. Box and whisker plot of cardio-respiratory 6 min run test (m.min^{-1}) for 17 year-old boys.