A 3 year longitudinal analysis of changes in Fitness, physical activity, fatness, and screen time

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Short Title: Changes in fitness, physical activity, screening and BMI

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Abstract

Aim: To analyze whether changes in physical activity index (PAI), screen time (ST: television and computer), and body mass index (BMI) made a contribution to longitudinal changes in Fitness of children and adolescents. Additionally, we analyzed interaction between baseline fitness level and changes in fitness. Methods: This is a 3-years longitudinal study of 345 high school students aged 11-19 years. Students performed curl-ups, push-up, and 20m shuttle run tests from Fitnessgram. PA and ST were evaluated using a standard questionnaire. Standardized scores of fitness tests were summed. Changes over time, were calculated Δ_1 (2007 minus 2006), Δ_2 (2008 minus 2007), and Δ_3 (2008 minus 2006). Results: Changes in PAI were positively and independently associated with changes in fitness in Δ_1, Δ_2, and Δ_3. Changes in BMI were negative associated with changes in fitness in Δ_3. Participants highly fit at baseline were those who showed positive changes in PAI over Δ_3, decreased changes ST and had the lowest increase in BMI over three years compared with who were low-fit at baseline.

Conclusions: Changes in BMI were associated with changes in fitness over 3 years. However, changes in PAI were the best predictor for changes in Fitness in each year and over the 3 years of evaluation in youth.

Key words: BMI, habitual physical activity, physical fitness, sedentary time, youth.

Introduction

Physical fitness (PF) is one of the most important targets in preventing childhood obesity by the recognition of its relationship with physical activity habits, health and welfare. There are evidences that pointed out a decline in PF [strength and cardiorespiratory fitness (CRF)] about 0.36% per year, since the decade of the 1970's related to social, behavioural, physical, physiological and psychological factors (1) in different ages, genders and geographic areas (2-5). On the other hand, it is generally recognized that PF can be an indicator of physical activity (PA) levels (6, 7) and longitudinal findings suggested a decline in PA especially in moderate to vigorous PA (MVPA) youth as a consequence of sedentary behaviours (8). Given these evidences it has been recommended not only to reduce of sedentary activities (to at least an average of two hours per day) (9) but also the promotion of 60 minutes or more of MVPA, at least 5 days/week for children and adolescents (10).

Fitness has been proposed as a major marker of health status at any age (11) and low fitness is associated with high fatness and low PA (12, 13). Further, some data showed that children are loosing the metabolic effect of fitness that might protect them from excessive weight gain as well as other metabolic diseases (12). On the other hand PF levels track from childhood to adolescence, and from adolescence to adulthood (13) with moderate to strong coefficients for CRF and strength (14) as well as PA (15) and obesity (16).

However, at the best of our knowledge few longitudinal studies have addressed this issue. Therefore, this study aimed to examine the association between changes in PAI, ST and BMI with changes in PF over a 3-year period, and to analyse the influence of fitness levels at baseline in those changes.

Methods

Participants and data collection

This is a school-based longitudinal study carried out in a middle and high public school from suburban setting comprising all the students from the 7th until 12th grade. Over a period of 3 years, from 2005 to 2008, 345 students, (147 boys, 42.6%) were followed with starting ages from 11 to 19 years. All students were invited to perform fitness tests and to answer a questionnaire. *Fitnessgram* battery is included in the national curriculum; however, participation was voluntary for all evaluations. Therefore, a letter informing families that students would be measured was sent home two weeks before measurements took place each year. Written consent was required. The Portuguese Ministry for Science and Technology provided permission to conduct this study.

Physical Fitness

Health-related components of PF were evaluated using the FITNESSGRAM battery test. Procedures described from Test User's Manual was used for all tests (17). The PE teachers involved in this project undertook training sessions, worked together each year, with qualified staff in order to assure the standardization, and reliability of the measurements. Students were familiarized with the procedure for each test before recording data. Further, the participants received verbal encouragement from the investigators in order to achieve maximum performance.

Three tests of the *Fitnessgram* battery recommended in the Portuguese National Program were used for this analysis: Curl-Up (CU), Push-Up (PU), and maximal multistage 20m shuttle-run (20m-SR).

Physical Activity Index

PA was assessed by a questionnaire (18). Application to a Portuguese population has previously been described elsewhere, with good reliability (ICC: 0.92–0.96) (19). A significant and negative correlation was found between the index of physical activity and heart rate at rest, serum insulin and skin fold measurements, and assumed as indication of validity of activity measure (20). The questionnaire had five questions with four or five choices (four/five-point scale): i) Do you take part in organized sport outside school? ii) Do you take part in non-organized sport outside school? iii) How many times per week do you take part in sport or physical activity for at least 20 minutes outside school? iv) How many hours per week do you usually take part in physical activity so much that you get out of breath or sweat outside school? v) Do you take part in competitive sport? The overall maximum number of points possible was 22. A PA Index (PAI) was obtained according to the total sum of the points with increasing ranks from the sedentary to vigorous activity levels.

Screen Time

Time spent watching television (TV Time) and using computer (PC Time) was measured with a questionnaire. Participants were asked how many hours and minutes they usually watched television or used a computer for work and for leisure during the day preceding the examination (weekdays) and during the weekend. Hours were converted to minutes (21) and summed to obtain a screen time (ST) score.

Statistical analysis

Mean and standard deviations described anthropometrics, PAI, ST, BMI and fitness. PF tests (curl-ups, push-up and 20mSR) were standardized (Z-scores). Then ,the three Z-scores were summed to construct a composite Z score (ZPF). For participants who were evaluated at the three time points, repeated measures analysis of variance was used to compare mean values at different time points, (2006, 2007 and 2008). Pairwise comparisons were made for each variable and Bonferroni correction was used. To analyze how variables changed over time, Δ_1 (2007 minus 2006), Δ_2 (2008 minus 2007), and Δ_3 ((2008 minus 2006) were calculated. Multiple linear regressions were used to examine associations between changes (Δ) in PAI, ST, BMI (as independent variables) and Δ ZPF (as dependent variables) over time. Variables were analyzed separately in an unadjusted model, and in a model successively adjusted for age, gender, ZPF at baseline, interaction of each variable with gender, ΔBMI, and ΔST. An additional analysis was made for the mean ΔPAI, ΔST and ΔBMI over time according to baseline fitness level. Participants were categorized as “low-fit” group if PF scores were lower than the first tertile and the “fit” group otherwise. Standardized scores of Δ_3PAI, Δ_3ST and Δ_3BMI were also calculated and Independent-Sample T test was used to find differences between these variable according to fitness categories at baseline. The level of significance was set at $p \leq 0.05$. Data were analyzed using SPSS Statistical Package for Social Science for windows version 17 (SPSS Inc., Chicago, IL, USA).

Results

Participants' anthropometric characteristics and variables considered for analysis are presented in Table 1. In general, all variables showed increased values ($p>0.05$) over time (Δ_3). Participants spent more time watching TV than using computer over a 3-year period (Δ_3), however no statistical significant differences were found with regard ST over the same period. Further, while mean scores of CU, PU and 20-m SR increased over time (Δ_3), additional differences were found for Shuttle Run in Δ_1 and $\Delta_{2.}$

Insert table 1

As can been seen in table 2, ΔPAI is positive and significantly associated with ΔPF, after adjustments for age, gender, and Fitness at baseline. The stronger independent association for the adjusted models was observed in Δ_3. On the other hand, both unadjusted and adjusted models showed that ΔPAI and ΔBMI were significantly associated with ΔPF in Δ_3 period.

In figure 1 it is depicted the comparisons between low fit group and fit group at baseline for PAI (1a); BMI (1b) and ST (1c), respectively. Fit participants were more active for each given point, while those who were low-fit showed higher BMI comparing with fit peers. For ST (figure 1C) there was a marked negative slope from 2006-2007 and an increased ST for 2007-2008 for both groups, although low-fit participants showed higher levels of ST.

Insert Figure 1

Discussion

The main purpose of this study was to examine how ΔPAI, ΔST and ΔBMI, are associated with ΔPF over time (3 year-period) and to analyze the importance of fitness level at baseline on this changes.

The main finding of this study was that our results showed that maintaining positive ΔPAI, was positive and significantly associated with ΔPF over time, independently of age, gender, fitness levels at baseline, BMI and ST. On the other hand, our data also showed that those with higher fitness level at baseline had higher PAI levels at each given period (Δ_1, Δ_2, Δ_3), showed positive ΔPAI. In contrast, those with low fitness at baseline had a slight decrease in PAI over the three years period. In addition, linear regressions pointed out an inverse association between ΔBMI and ΔPF. However, when adjusted for fitness at baseline, no statistical significant results were found, which might suggest that the relationship between ΔBMI and ΔPF can be somewhat explained by fitness levels at baseline. These outcomes are worthy to notice because it was suggested that preventive efforts focused on maintaining and increasing PF and PA through puberty will have favourable health benefits in later years (22).

Furthermore, the least fit participants gained more weight comparing to their fit peer. This data agree with evidences suggesting that participants whose PF remained high over time have less adiposity and abdominal adiposity than their low-fit peers (23). Further, in accordance with our results other studies have shown that PF at baseline was inverse and significantly associated with adiposity (BMI and skinfolds), as well as other CVD risk factors (24). Besides, a study showed that low-fit children were more likely to be BMI gainers than those classified as fit at baseline (25). This slight positive ΔBMI gain in high-fit participants can also be explained by the increased muscle mass. However, this issue cannot be explored, as we did not have direct measure of lean mass.

In our study, participants with higher fitness levels at baseline had also negative ΔST. Nevertheless, linear regressions showed no associations between ΔST and ΔPF, which, however, it is difficult to compare because limited information has been published on the association between ST over time and fitness (26).

Strengths of this study are its longitudinal design with repeated measures, which allowed us to measure changes in PF, PAI, BMI and ST over time. These findings are important because they provide a data base for monitoring future trends in this population. The ease of administration of FITNESSGRAM tests and its common use in large-scale studies makes a valuable tool for studying fitness condition in a school population. Recently, the Portuguese curriculum program for Physical Education included the FITNESSGRAM battery test, which is an important step for students' population scrutiny related to health conditions. Effective community-based programs are needed to include a culture of active habits and to offer further opportunities to increase PA and PF.

Nonetheless, limitations should also be recognized. First, the use of a questionnaire to estimate the time spent watching TV or using computer can be somehow difficult for children. Youngsters have difficulties to recall, quantify, and categorize this type of information about their behaviour. In addiction, there is the lack of questionnaire validation for ST and PAI against accelerometers. Another limitation was the absent of sexual maturation in a period of rapid growth. BMI is an accepted measure, however, does not capture variations in fat mass and fat free mass that can be differentially related to PF. Nevertheless, the most of the variance in obesity-related anthropometrics is capture by BMI, and it is equally well correlated with fat mass and waist circumference (27).

In conclusion, our data showed that many children and adolescents changed their levels of PA, BMI, ST and PF over time. However, ΔPAI seemed to be the best indicator for ΔPF in youth. The results might also reinforce the attempt to work out strategies to increase PA levels, leading the to improvements in the PF levels and counteraction of the increased obesity prevalence. However, more longitudinal studies are needed to ascertain the direction and sequence of associations of PF, PA and obesity.

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Table 1 – Description of participants for means and standard deviation.

		2006		2007		2008	
	N	Mean	SD	Mean	SD	Mean	SD
Weight (kg)	225	56.83[a]	11.86	59.52[b]	11.37	62.45	11.25
Height (m)	226	1.64[a]	0.09	1.66[b]	0.08	1.68	0.08
BMI (kg/m^2)	225	20.74[a]	3.6	21.67[b]	3.44	22.16	3.37
Fitness (ZFP) *	185	0.34	2.45	0.15	2.38	0.25	2.28
Curl-Ups (n rep)	217	36.03[b]	24.02	39.46	22.5	50.88	21.70
Push-ups (n rep)	217	11.53[b]	9.10	12.36	8.65	17.53	9.61
20-m SR (n laps)	233	36.53[a]	20.83	43.17[d]	20.91	49.02	22.95
PAI #	136	12.3	4.08	12.6	4.0	12.7[c]	4.9
Screen Time	164	162.1	70.1	149.9	66.6	150.8	68.4
TV time (min)	161	208.4[b]	99.1	194.5	91.1	174.5	95.7
PC time (min)	153	119.9[b]	75.7	104.8	65.0	124.4	66.9

Repeated measures analysis of variance used to test for mean differences between the three time points; Adjustment for multiple comparisons with Bonferroni; the mean difference is significant at the 0.05 level;

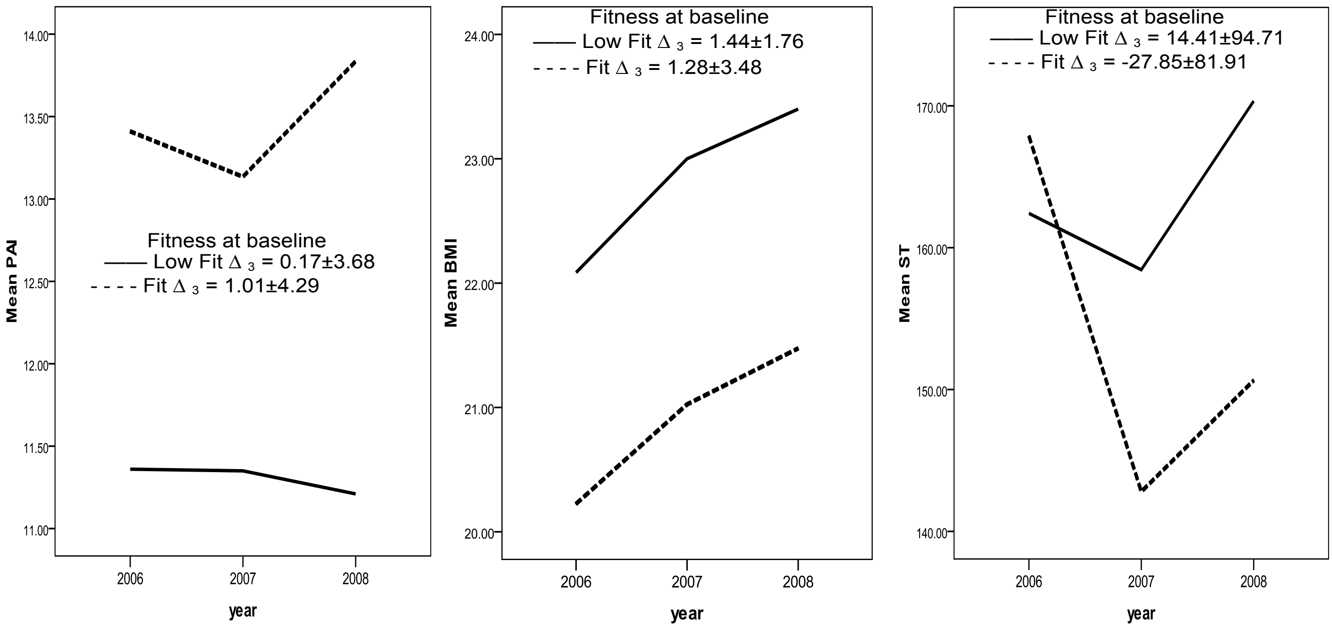
* Sum of the standardized fitness tests (Curl-ups, Push-ups and Shuttle run-20m);

Ranges from 5 (lowest active) to 22 (most active)

[a] Significantly different from 2007 and 2008; [b] Significantly different from 2008; [c] Significantly different from 2007; [d] Significantly different from 2006

Table 2 - Multiple linear regressions regarding the relationship between changes in PF and changes in PAI, BMI and ST across three years. Dependent Variable: Changes in Δ_1ZPF, Δ_2ZPF and Δ_3ZPF; β - Standardized coefficients. Confidence interval (CI 95%)

	Δ_1 (2006-2007)				Δ_2 (2007-2008)				Δ_3 (2006-2008)		
	β	**(CI 95%)**	***p***		**β**	**(CI 95%)**	***p***		**β**	**(CI 95%)**	***p***
Unadjusted Models											
Δ_1 PAI	0.114	(-0.013;-0.137)	NS	**Δ_2 PAI**	0.071	(0.001;0.140)	0.047	**Δ_3 PAI**	0.111	(0.026;0.196)	0.011
Δ_1BMI	-0.045	(-0.131;0.071)	NS	**Δ_2BMI**	-0.127	(-0.173;0.006)	0.066	**Δ_3 BMI**	-0.145	(-0.275;0.000)	0.050
Δ_1ST	0.005	(-0.005;0.005)	NS	**Δ_2ST**	-0.033	(-0.555;-0.332)	NS	**Δ_3 ST**	-0.071	(-0.006;-0.003)	NS
Adjusted Models											
Δ_1 PAI	0.087	(-0.026;-0.148)	0.005	**Δ_2 PAI**	0.072	(0.004;0.139)	0.037	**Δ_3 PAI**	0.138	(0.37;0.238)	0.008
Age	0.280	(-0.059;0.35)	NS	**Age**	0.108	(-0.098;0.313)	NS	**Age**	0.135	(-0.099;0.368)	NS
Gender	1.334	(0.780;1.88)	0.000	**Gender**	0.626	(0.112;0.139)	0.017	**Gender**	1.034	(0.378;1.690)	0.002
ZPF Baseline	-0.517	(-0.642;-0.39)	0.000	**ZPF Baseline**	-0.177	(-0.284;-0.071)	0.001	**ZPF Baseline**	-0.547	(-0.678;-0.415)	0.000
								Δ_{tot}PAI*gender	-0.019	(-0.154;0.117)	NS
								Δ_{tot}ST	-0.002	(-0.006;0-002)	NS
								Δ_{tot}BMI	-0.022	(-0.175;0.131)	NS
Adjusted Models											
Δ_1 BMI	-0.067	(-0.132;0.041)	NS	**Δ_2 BMI**	-0.127	(-0.173;0.006)	NS	**Δ_3 BMI**	-0.157	(-0.292;-0.023)	0.022
								age	-0.317	(-0.534;-0.100)	0.004
								gender	0.611	(0.038;1.184)	0.037
Adjusted Models											
Δ_1 ST	-0.023	(-0.005;0.003)	NS	**Δ_2 ST**	-0.042	(-0.004;0.002)	NS	**Δ_3 ST**	-0103	(-0.006;-0.001)	NS



1a 1b 1c

Figure 1 - Mean of absolute values of PAI, BMI and ST at the three time points 2006, 2007 and 2008 and mean ± SD for Δ_3 by low-fit vs. fit at baseline.