Changes in Fitness, physical activity, fatness, and screen time: A longitudinal study in children and adolescents

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Abstract

Objective: To analyze whether changes in Physical Activity Index (PAI), sedentary time (ST; TV and PC use), and Body Mass Index (BMI) made a significant contribution to longitudinal changes in Physical Fitness (PF) of children and adolescents. Additionally, we analyzed interaction between baseline fitness level and changes in fitness.

Methods: This is a three years longitudinal study of 345 high school students aged 11-19 years. Students were invited to perform tests from Fitnessgram battery for strength (curl-ups, push-up), and Cardiorespiratory fitness (20m-shuttle run). PAI and ST were evaluated using a standard questionnaire. Standardized scores of physical fitness tests were summed (ZPF). Changes over time, were calculated Δ_1 (TP_1 minus TP_0), Δ_2 (TP_2 minus TP_1), and Δ_{total} (TP_2 minus TP_0).

Results: Changes in PAI were positively and independently associated with changes in ZPF in Δ_1, Δ_2, and Δ_{total}. No significant associations of ΔST and ΔZPF were found. ΔBMI was negative associated with ΔZPF in Δ_{total}. Participants with higher fitness levels at baseline were those who showed positive changes in PAI over Δ_{total}, decreased screen time and had the lowest increase in BMI over three years compared with those who were low-fit at baseline.

Conclusions: Changes in PAI were the best predictor for changes in Fitness in children and adolescents in each year and over the three years of evaluation. BMI changes were associated with longitudinal changes in PF.

Introduction

Recent studies have been given increasingly interest to Physical Fitness (PF) by the recognition of its relationship with physical activity habits, health and welfare. There is evidence from longitudinal studies that physical activity (PA) and PF have declined in the last decades (1-3) as a consequence of sedentary behaviours that characterize the free time entertainment of these new generations (4, 5). ST have been shown to be associated with PA (6), other studies have found no association at all (7-9). Also, reducing screen time could contribute to prevent obesity (10, 11).

Low fitness is associated with high fatness and low PA (12, 13) and the existing evidence points to a critical decrease of overall fitness levels (14). Therefore, increasing PA and PF may protect youth from excessive weight gain as well as other metabolic disorders (15).

PF levels track from childhood to adolescence, (16) and from adolescence to adulthood (17-20) with moderate to strong coefficients for CRF and strength (19, 21, 22). The same situation occurs for PA (23) and obesity (24, 25). PA has been promoted as a lifelong positive health behaviour in children and adolescents (26) and fitness has been proposed as a major marker of health status at any age (27).

Thus, it is particularly important to investigate and promote positive behaviors in early ages as part of a strategy for achieving optimal adult health. Longitudinal studies in children are scarce and finding not consistent. Therefore, this study aimed to examine the association of the changes in PAI, ST and BMI with PF changes over three academic years and if there was some 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 (28). The *Fitnessgram* is included in Physical Education curriculum of Portuguese National Program. 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 (measuring abdominal strength and endurance): students lie down with knees bent and feet unanchored. Set to a specified pace, students complete as many repetitions as possible to a maximum of 75); Push-Up (measuring upper body strength and endurance): students were lying on the floor supported at the feet and the hands, face down and straight arms. They lowered the body to a 90-degree elbow angle and push up. Set to a specified pace, students complete as many repetitions as possible. CRF was predicted by maximal multistage 20m shuttle-run (20m-SR) test One lap represented jogging or running from one set of cones to the other. The test was terminated either due to volitional exhaustion or because the participant could not keep up the required speed for two laps. The result was recorded as laps taken to complete the 20m-SR. Procedures described from FITNESSGRAM Test User's Manual (29) was used for all tests. Standardized scores of each test were summed to create a new variable representing PF.

Physical Activity Index

PA was assessed by a questionnaire (30). Application to a Portuguese population has previously been described elsewhere (31). 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 (32). The questionnaire had five questions with four answer choices (four-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 assessed with a questionnaire. Participants were asked how many hours and minutes they usually watched television or used a computer, for work and for leisure, in the day preceding the examination (weekdays) and during weekend: (i) How much time per day do you spend watching TV? (ii) How much time per day do you use your computer to work or study? (iii) How much time per day do you use your computer for leisure? Hours were converted to minutes.

Statistical analysis

Standardized scores of physical fitness tests (curl-ups, push-up and 20m-SR) were summed (ZPF) to construct a composite score. Mean and standard deviations described participants characteristics: anthropometrics, PAI, ST (TV time and Computer time), BMI and fitness. 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, (TP_0, TP_1 and TP_2). Pairwise comparisons were made for each variable and Bonferroni correction was used. To analyze how variables changed over time, Δ_1 (TP_1 minus TP_0), Δ_2 (TP_2 minus TP_1), and Δ_{total} (TP_2 minus TP_0) were calculated. Multiple linear regressions were used to examine associations between changes in PAI, ST, BMI (as independent variables) and changes in ZPF (as dependent variables) over Δ_1, Δ_2, and Δ_{total}. Variables were analyzed separately in an unadjusted model, and in a model successive adjusted for age, gender, ZPF at baseline, interaction of each variable with gender, ΔBMI, and ΔST. An additional analysis was made for the mean of changes in PAI, ST and BMI over Δ_{total}, stratified by "low-fit" group if participants' values were lower then the first tertile and the "fit" group otherwise. In Δ_2, Fitness at baseline corresponds to the values of TP_1 (2007). For graph analysis, Z scores of Δ_{total}PAI, Δ_{total}ST and Δ_{total}BMI were calculated and Independent-Sample T test was used to find differences between these variable according to fitness at baseline and McNemar Test to compare the percentage of participants maintaining or changing fitness condition.

The level of significance was set at $p \leq 0.05$. Data were analyzed using SPSS (Windows version 15.0).

Results

Participants' anthropometric characteristics and variables considered for analysis are presented in Table 1. Most of variables show increased values as participants progressed from TP_0 to TP_2. Participants, showed a significant increase of weigh, height from TP_0 to TP_1 and to TP_2. The same occurred for BMI, although without differences between TP_1 and TP_2. Throughout the three years period, participants spent more time watching TV than using computer, with differences between TP_0 and TP_2, however no significant differences were found for the whole screen time over the three time points.

Insert table 1

Figure 1 shows that mean values of curl-ups and Shuttle Run increased over the three years, with differences between TP_0 and TP_2 as well as TP_1 and TP_2 and additional differences between TP_0 and TP_1 for Shuttle Run.

Insert Figure 1

Table 2 shows mean values of changes in Δ_0, Δ_1 and Δ_{total}. Positive changes were found in PAI and BMI, although with large standard deviations.

Insert Table 2

As can been seen in table 3, changes in PAI showed positive associations with changes in Fitness, reaching significance at the three time points after adjustments for age, gender, and Fitness at baseline. The most evident result for adjusted models was observed over Δ_{Total} (2006-2007), showing the strong and independent association between ΔPAI and ΔPF. Both unadjusted and adjusted models showed that PAI and BMI changes were significantly associated with Fitness changes between 2006 and 2008.

Insert table 3

Percentages of participants in fitness categories were calculated to find changing's or maintenance fitness condition from baseline (fig. 2). The majority of the participants (56%) maintained fitness levels, over the years. There were more participants, 16.8%, changing from low-fit to fit category, comparing to the 23% of participants that changed from fit to low-fit level, then the opposite (11.2%) from 2006 to 2008.

Insert Figure 2

Figure 3 shows the mean (95%CI) of Z scores of PAI, ST and BMI changes over the time (Δ_{total}), stratified by fitness at baseline. Participants were defined “low-fit” in the first tertile and “fit” otherwise at TP_0. Those with low fitness level at baseline showed negative changes in total PAI, and positive changes in total ST and total BMI. However those with higher fitness levels at baseline were those who had positive changes in PAI, decreased ST and had the lowest positive change in BMI over three years compared with those who were low-fit at baseline.

Insert Figure 3

In figure 4A participants with low mean of fitness levels at baseline showed lower PAI levels in TP_0, TP_1 and TP_2, comparing with those with higher fitness at baseline. In figure 4B fit and low-fit participants at baseline increased BMI and those who were low-fit at baseline showed higher BMI comparing with fit peers. For ST (figure 4C) there was a marked negative slope from TP_0 to TP_1 and an increase between TP_1 and TP_2 for those who were fit at baseline. An identical tendency occurred for low-fit at baseline, although with higher levels of ST.

Insert Figure 4

Discussion

The main purpose of this study was to examine how changes in physical activity index, screen time and body mass index have influenced changes in fitness levels over time and to recognize the importance of fitness level at baseline in this process of change. The results revealed that preserving positive changes in PAI could influence positive changes in fitness over time, independently of age, gender, fitness levels at baseline, BMI and ST between 2006 and 2008. Comparing these results according to fitness levels at baseline, those with higher fitness levels at baseline had higher PAI levels each year and positive changes in PAI, in contrast those with low fitness at baseline had a slight decrease in PAI over the three years of evaluation. A study carried out by Baquet et al., (33) over a period of 4 years, the regularly active group of that study, also further increased their PF performance compared with the sedentary groups. These authors concluded that from childhood to adolescence, increasing PA was not necessary to be fit, because children who were most active were also the fittest. Although with different methods of analyses our results differ in part with the latter work, showing that changes in PAI were associated with fitness changes independently of fitness level at baseline, meaning that a further increase in PAI over the years in children and adolescents, resulted in increased fitness.

There is evidence indicating that subjects whose physical fitness remained high over time have less adiposity and abdominal adiposity than peers (16). Our results from linear regressions showed also inverse associations between changes in BMI and changes in PF. However, when we adjusted fitness at baseline to the model, non-significant results were found which might suggest that the relationship between changes in BMI and changes in PF can be somewhat explained by fitness levels at baseline. Comparing fit participants at baseline with low-fit peers, the fittest had the lowest positive change in BMI over the three years of evaluations. This slight positive change of BMI can be explained by the development of bigger lean (via muscle) mass. However this issue cannot be explored, as we did not have direct measure of lean mass. Even though, in accordance with our results, other studies have shown that PF at baseline was inversely related to adiposity (BMI and skinfolds) (34) and that low-fit children were more likely to be BMI gainers than those classified as fit at baseline (35). PF has been associated with other risk factors besides obesity. Fitness in adolescence have been found to be modestly but beneficially associated with cardiovascular diseases (CVD) risk factors; high fitness levels at baseline were associated with lower total cholesterol and triglycerides, higher HDL and blood pressure (systolic and diastolic) (34, 36).

In our study, participants with higher fitness levels at baseline had also negative changes in ST. Nevertheless, linear regressions showed no associations between changes in ST and changes in PF. This might be related to inaccuracy of measurements. The use of a questionnaire to estimate the time 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 behavior. In fact this limitations must be recognized, and the use of subjective measurements not only for ST but also for physical activity may solve this problem. Another limitation was the absent of sexual maturation in a period of rapid growth. Further, body fat was assessed indirectly through BMI. It is a common way of assessing overweight/obesity, however, BMI 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 (37). The strength of this study is the longitudinal design with repeated measures. 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.

In conclusion, longitudinal results showed that many children and adolescents changed their levels of PA, BMI, ST and PF. However changes in PAI seemed to be the best indicator for fitness changes in youth over time.

The results of our study can reinforce the attempt to work out strategies to increase PA levels to improve Fitness levels and counteract the wide-ranging increase of obesity. However more longitudinal studies are needed to ascertain the direction and sequence of associations of PF, PA and obesity.

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Figure 1 - Mean and Standard Deviation of fitness performances in each time point of evaluation.

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

Figure 2 - McNemar Test for percentage of participants maintaining fitness condition, changing from fit to low fit or from low fit to fit during $\boldsymbol{\Delta_0}$ (p=0.314), **Δ1** (p=1.000) and **Δtotal** (p=0.136). Defined “low-fit” for values lower then the first tertile and “fit” otherwise.

Figure 3 – Z scores of changes in PAI. ST and BMI across Δ_{total} according to fitness level at baseline

Independent-Sample T test. [a] significantly different from ST fit at baseline (t= 2.692; p=0.008)

Figure 4 - Mean of absolute values of PAI. BMI and ST at the three time points TP_0. TP_1 and TP_2 by low-fit vs. fit at baseline

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

		TP_0		TP_0		TP_2	
	N	Mean	SD	Mean	SD	Mean	SD
Weight	225	56.83[a]	11.86	59.52[b]	11.37	62.45	11.25
Height	226	1.64[a]	0.09	1.66[b]	0.08	1.68	0.08
BMI	225	20.74[a]	3.6	21.67[b]	3.44	22.16	3.37
Fitness [1]	185	0.34	2.45	0.15	2.38	0.25	2.28
PAI	136	12.3	4.08	12.6	4.0	12.7	4.9
Screen Time	164	162.1	70.1	149.9	66.6	150.8	68.4
TV time	161	208.4[b]	99.1	194.5	91.1	174.5	95.7
PC time	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;
[1] Sum of the standardized fitness tests (Curl-ups, Push-ups and Shuttle run-20m);
[a] Significantly different from 2007 and 2008; [b] Significantly different from 2008; [c] Significantly different from 2007; [d] Significantly different from 2006

Table 2 – Description of changes in Z-scores of Fitness, Physical Activity Index, Screen Time and Body Mass Index.

Variables	N	Mean	SD	Min.	Max.
Δ_0 ZPF	233	-0.16	1.83	-5.94	5.86
Δ_1 ZPF	215	0.07	1.33	-3.60	3.93
Δ_{total} ZPF	232	-0.14	1.98	-6.71	5.96
Δ_0 PAI	197	0.13	4.38	-15.00	14.00
Δ_1PAI	185	0.50	3.50	-9.00	12.00
Δ_{total} PAI	154	0.57	4.16	-16.00	13.00
Δ_0 ST	221	-8.89	76.73	-202.50	312.50
Δ_1ST	211	3.84	77.51	-247.50	315.00
Δ_{total} ST	177	-11.17	85.41	-225.00	285.00
Δ_0 BMI	244	0.89	2.52	-12.23	16.59
Δ_1BMI	302	0.55	1.96	-15.13	11.86
Δ_{total} BMI	234	1.38	2.43	-11.24	15.41

Table 3 - Multiple linear regressions regarding the relationship between changes in Physical Fitness and changes in PAI. BMI and ST across three years. Dependent Variable: Changes in Δ_0 ZPF. Δ_1ZPF. Δ_{total} ZPF β- Standardized coefficients. Confidence interval (CI 95%)

	Δ_0 (2006-2007)				**Δ_1 (2007-2008)**				**Δ_{Total} (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)	0.104	**Δ_2 PAI**	0.071	(0.001;0.140)	0.047	**Δ_{Total} 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_{Total} 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_{Total} ST**	-0.071	(-0.006;-0.003)	0.447
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_{Total} 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_{Total} 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_1	-0.023	(-0.005;0.003)	NS	**Δ_2 ST**	-0.042	(-0.004;0.002)	NS	**Δ_{Total} ST**	-0103	(-0.006;-0.001)	NS

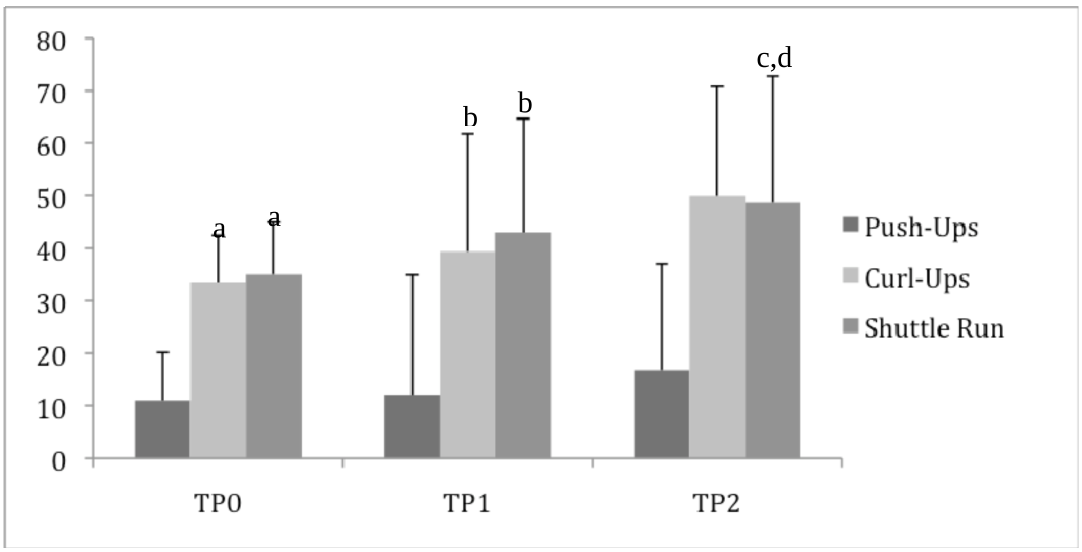
80
70
60
50
40
30
20
10
0
a
a
b
b
c,d
TP0
TP1
TP2
Push-Ups
Curl-Ups
Shuttle Run

Figure 1

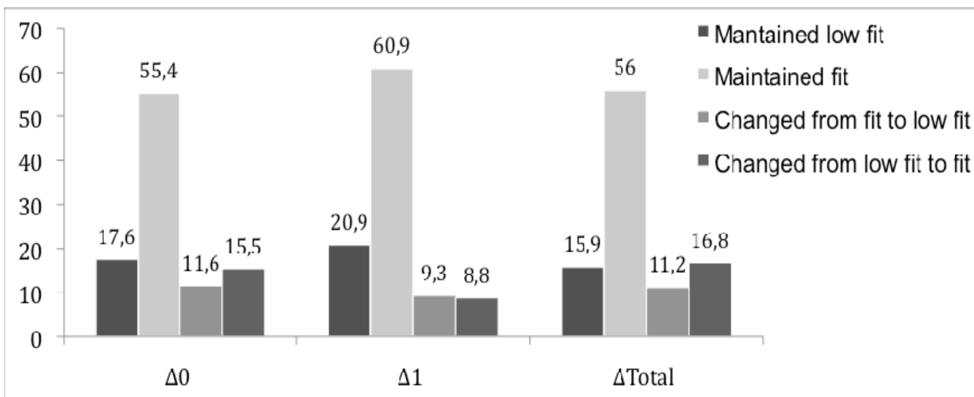
70
60
50
40
30
20
10
0
17,6
55,4
11,6
15,5
20,9
60,9
9,3
8,8
15,9
56
11,2
16,8
Δ0
Δ1
ΔTotal
Mantained low fit
Maintained fit
Changed from fit to low fit
Changed from low fit to fit

Figure 2

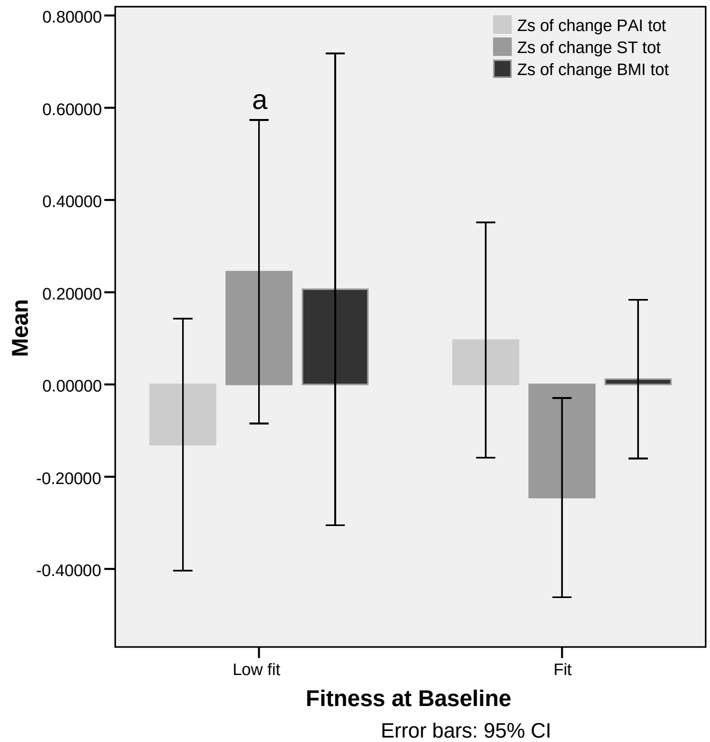
Zs of change PAI tot
Zs of change ST tot
Zs of change BMI tot
a
0.80000
0.60000
0.40000
0.20000
0.00000
-0.20000
-0.40000
Mean
Low fit
Fit
Fitness at Baseline
Error bars: 95% CI

Figure 3

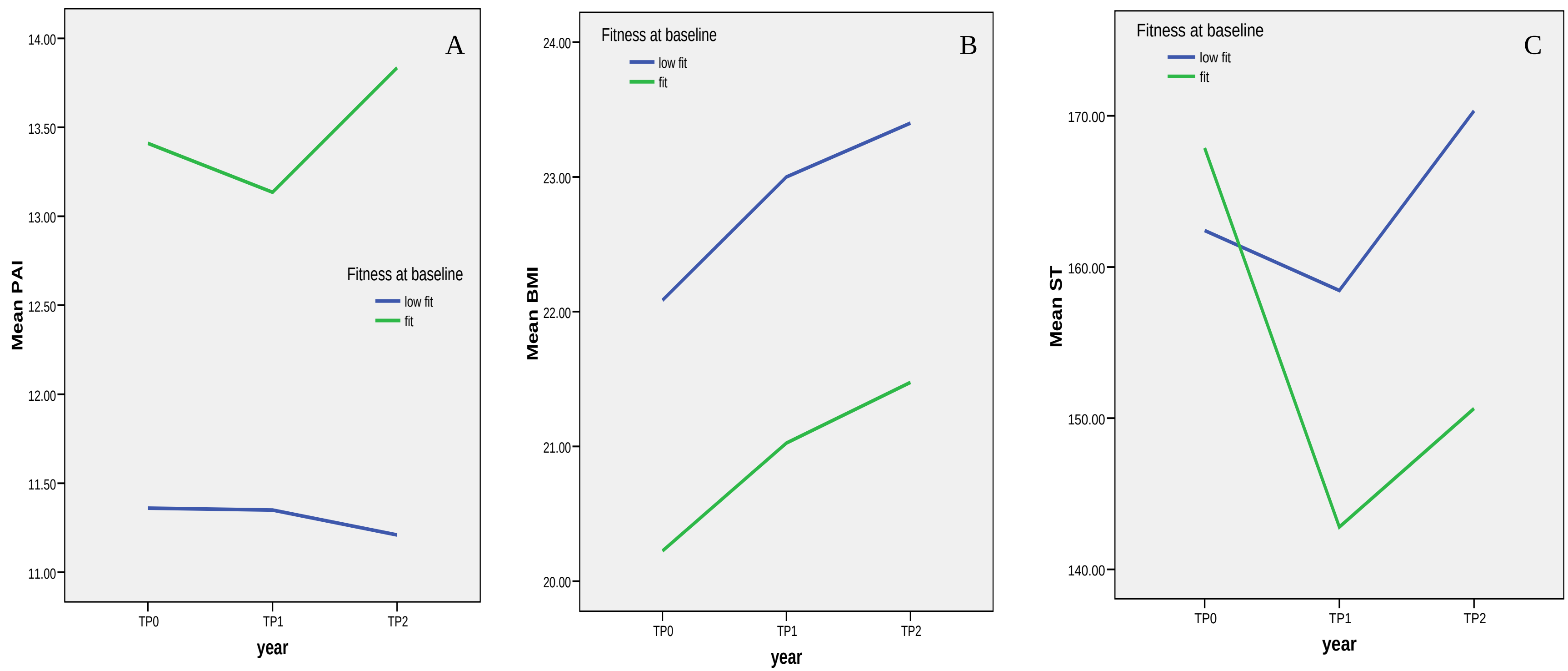
A
Mean PAI
14.00
13.50
13.00
12.50
12.00
11.50
11.00
Fitness at baseline
low fit
fit
TP0
TP1
TP2
year
B
Mean BMI
24.00
23.00
22.00
21.00
20.00
Fitness at baseline
low fit
fit
TP0
TP1
TP2
year
C
Mean ST
170.00
160.00
150.00
140.00
Fitness at baseline
low fit
fit
TP0
TP1
TP2
year

Figure 4