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Cardiorespiratory fitness and nutritional status of schoolchildren: 30-year evolution☆

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KEYWORDS
Nutritional status;
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Abstract
Objective: To compare the changes in cardiorespiratory fitness in evaluations performed every ten years since 1978/1980, according to the nutritional status and gender of students in the city of Ilhabela, Brazil.
Methods: The study is part of the Mixed Longitudinal Project on Growth, Development and Physical Fitness of Ilhabela. The study included 1,291 students of both genders, aged 10 to 11 years old. The study periods were: 1978/1980, 1988/1990, 1998/2000, and 2008/2010. The variables analyzed were: body weight, height, and cardiorespiratory fitness (VO_{2max} - L.min-1 and mL.kg-1.min-1) performed using a submaximal progressive protocol on a cycle ergometer. Individuals were classified as normal weight and overweight according to curves proposed by the World Health Organization of body mass index for age and gender. Analysis of variance (ANOVA) with three factors followed by the Bonferroni method were used to compare the periods.
Results: The number of normal weight individuals (61%) was higher than that of overweight. There was a significant decrease in cardiorespiratory fitness in both genders. Among the schoolchildren with normal weight, there was a decrease of 22% in males and 26% in females. In overweight schoolchildren, males showed a decrease of 12.7% and females, of 18%.
Conclusion: During a 30-year analysis with reviews every ten years from 1978/1980, there was a significant decrease in cardiorespiratory fitness in schoolchildren of both genders, which cannot be explained by the nutritional status. The decline in cardiorespiratory fitness was greater in individuals with normal weight than in overweight individuals.

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PALAVRAS-CHAVE
Estado nutricional;
Aptidão física;
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Exercício aeróbico

Aptidão cardiorrespiratória e estado nutricional de escolares: evolução em 30 anos

Resumo
Objetivo: Comparar as mudanças da aptidão cardiorrespiratória em avaliações a cada 10 anos a partir de 1978/1980, de acordo com o estado nutricional e o sexo de escolares do município de Ilhabela, Brasil.
Métodos: O estudo faz parte do Projeto Misto-Longitudinal de Crescimento, Desenvolvimento e Aptidão Física de Ilhabela. Participaram do estudo 1.291 escolares de ambos os sexos, de 10 e 11 anos de idade. Os períodos analisados foram 1978/1980, 1988/1990, 1998/2000 e 2008/2010. As variáveis analisadas foram peso corporal, estatura e aptidão cardiorrespiratória ($VO_{2máx}$ - $L.min^{-1}$ e $mL.kg^{-1}.min^{-1}$) realizada por um protocolo progressivo submáximo em um ciclo ergômetro. Os indivíduos foram classificados em eutróficos e excesso de peso mediante as curvas propostas pela Organização Mundial da Saúde de índice de massa corporal para idade e sexo. Para comparar os períodos, foi utilizado a ANOVA com três fatores, seguida pelo método Bonferroni.
Resultados: A quantidade de eutróficos (61%) foi maior do que a de excesso de peso. Houve diminuição significativa da aptidão cardiorrespiratória em ambos os sexos. Entre os escolares meninos e as meninas eutróficas houve diminuição de 22% e 26%, respectivamente. Nos escolares com excesso de peso, os meninos diminuíram em 12,7%, e as meninas, em 18%.
Conclusão: Em uma análise de 30 anos, com avaliações a cada 10 anos a partir de 1978/1980, houve uma diminuição significante da aptidão cardiorrespiratória em escolares de ambos os sexos, que não pode ser explicada pelo estado nutricional. A queda da aptidão cardiorrespiratória foi maior nos escolares eutróficos do que nos obesos.

Introduction

Levels of physical fitness among young individuals have declined in recent years, contributing to the development of diabetes, hypertension, metabolic syndrome, and increased risk of metabolic and cardiovascular diseases in adulthood.[1] Approximately 80% of adolescents in the world do not obtain the recommended 60 minutes of moderate to vigorous physical activity per day,[2] which, combined with the significant socioeconomic changes in recent years, has resulted in the increase of overweight and obesity.[3]

The low levels of physical fitness and physical activity[4] are associated with overweight,[5] the growing prevalence of obesity, and the proportion of children with sedentary lifestyle, suggesting that levels of cardiorespiratory fitness may have decreased by random distribution among schoolchildren of different body composition.[6]

Cardiorespiratory fitness (VO_{2max}), measured in absolute values ($L.min^{-1}$) and relative to total body mass ($mL.kg^{-1}.min^{-1}$), has been used in order to make a real comparison of physical fitness among students with different heights.[1,5] Relative values are more often used for comparisons between individuals who differ in total body mass and lean mass, as the musculature involved in physical activity influences these variables.[7]

Several studies have associated changes in cardiorespiratory fitness over time with sedentary behavior, nutritional status, and anthropometric variables, particularly in developed countries.[8,9] However, the scenario in developing countries is different, and the number of studies in these countries is still small.[10–12]

Longitudinal studies appear to be more adequate for better understanding the behavior of physical fitness variables according to the nutritional status of a population over time. In Brazil, there have been few studies analyzing cardiorespiratory fitness according to the nutritional status over time, many of which were performed as part of the Mixed Longitudinal Project on Growth, Development and Physical Fitness of Ilhabela.[10,13]

Since cardiorespiratory fitness is an important component of metabolic syndrome (MS) and a strong predictor of premature death, the identification of changes in physical activity levels during the epidemic of obesity may indicate the need for interventions to improve the physical fitness of schoolchildren.[4] In this study, the hypothesis is that the decrease in physical activity, analyzed over a 30-year period, is occurring both among normal weight schoolchildren and overweight children. Thus, the aim of this study was to compare the changes in cardiorespiratory fitness through evaluations performed every ten years, from 1978/1980, according to the nutritional status and gender of schoolchildren in the town of Ilhabela, state of São Paulo, Brazil.

Material and methods

The present study is part of Mixed Longitudinal Project of Growth, Development. and Physical Fitness of Ilhabela, which has been uninterruptedly developed by CELAFISCS since 1978, with biannual evaluations performed in April and October. Over a 32-year period, there have been 68 evaluations, making this the most extensive and detailed study performed in a developing country in this area of knowledge. Its main characteristics are the use of non-sophisticated

equipment and non-complex techniques, making it simple and easy to apply in large groups. All evaluations are conducted by previously trained health professionals, performed over three consecutive days, aiming to collect data on physical fitness (anthropometric, metabolic, and neuromotor), physical activity levels, and nutrition in children aged 7 years and older, using standardized tests and measures.[14]

The town of Ilhabela is located on the northern coast of the state of São Paulo (Brazil), with a land area of 348 km^2. The study considered the data from the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística - IBGE) from 1980, 1991, 2000, and 2010 for the age range of 10 to 11 years. The town's population in 1980 consisted of 7,800 inhabitants, of which 394 were schoolchildren. By 1991, the town had 13,538 inhabitants, of which 641 were schoolchildren. In 2000, it had 20,836 inhabitants, of which 803 were aged 10 to 11 years. In 2010, the town population consisted of 28,176 inhabitants, of which 1,036 were schoolchildren aged 10 to 11 years.[15] The study sample (10 and 11 years of age) represents 47% of the town population in 1978/1980, 1988/1990, and 1998/2000 and 52% in 2008/2010, respectively. During the study period there was an increase in the population (3.6 fold), a proportional reduction of the schoolchildren in relation to the total population, and a change in economic activity, which has become predominantly service sector.

The study sample was created based on a database consisting of over 16,000 evaluations and 3,200 students of both genders, aged between 7 and 18 years, who participated in the evaluations between 1978 and 2011, with 1,291 students (Fig. 1: 726 males, 565 females) between 10 and 11 years who met the following inclusion criteria: (a) had a complete evaluation in one of the following years: 1978/1980, 1988/1990, 1998/2000, and 2008/2010; (b) were between 10 and 11 years of age, (c) were regularly enrolled in the school system of Ilhabela, (d) had no clinical or functional limitations to perform the stress test, (and) and had parents or tutors sign the informed consent, according to Resolution 196/96 of the National Health Council. The project was approved by the Ethics Committee of the Universidade Federal de São Paulo, protocol No. 0056/10.

The 1,291 students who participated in the study were submitted to four evaluations, spaced every ten years, performed over a 30-year period: 1978/1980, 1988/1990, 1998/2000, and 2008/2010.

All evaluations included body weight (kg) and height (cm) measurements. Body weight was obtained with the schoolchildren in the standing position, with their back facing the balance scale (Filizola Personal Life® model), with their feet apart. Then, they were placed in the center of the platform, in the standing position, while gazing at a fixed point in front of them.[14] Height was obtained using a stadiometer with a fixed base and movable cursor, with the schoolchildren in the standing position, bare feet with ankles side by side; all posterior regions of the heels, pelvic waist, scapular waist and occipital region surfaces were in contact with the stadiometer.

The measurements were recorded in inspiratory apnea to minimize possible variations regarding this anthropometric variable. The head was on the Frankfurt plane, parallel to the ground. The measurement was made with the cursor at a 90-degree angle relative to the scale.[14] Three consecutive

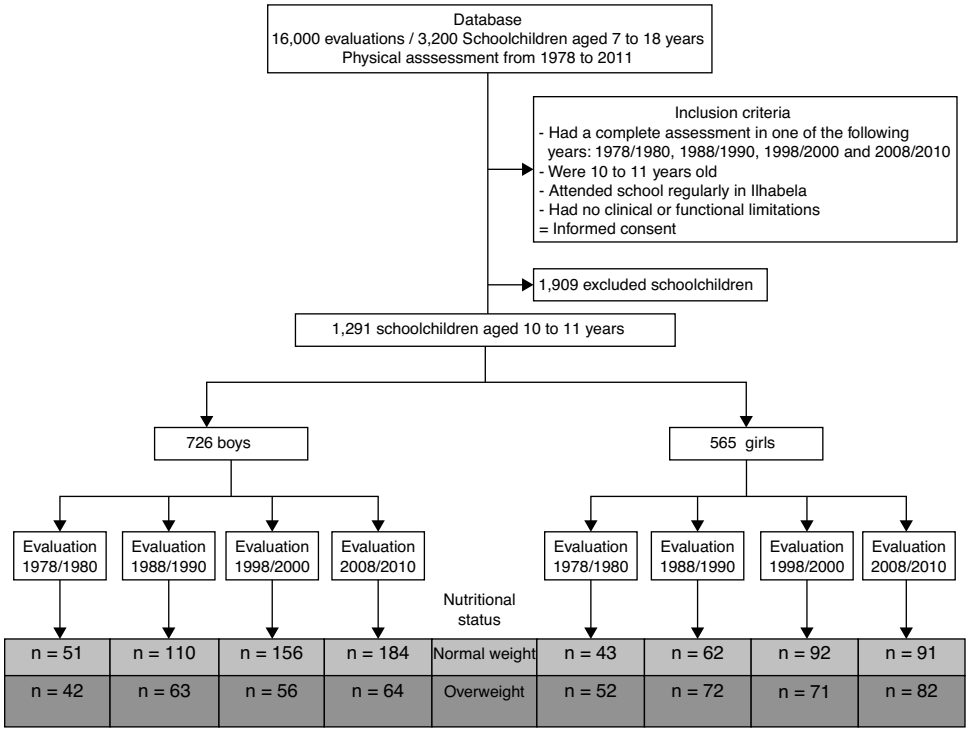

Figure 1 Flow chart with the description of the number of schoolchildren aged 10 to 11 years from Ilhabela included in the present study, according to the evaluation and nutritional status.

measures were obtained, and the arithmetic mean was considered as the final value.

Body mass index (BMI) was calculated using the two abovementioned measures. For the classification of nutritional status, the schoolchildren were classified as having normal weight when the z-score was between -1 and 1, and overweight when z-score > 1, according to the BMI curves proposed by the World Health Organization (WHO) for age and gender.[16] As children with a z-score less < -1 were excluded from the study, the present study is characterized by the comparison of two groups, one with normal weight and the other, overweight. This classification has been used to identify the risk of or the actual condition of obesity in populations.[9]

To assess cardiorespiratory fitness, aerobic power (VO_{2max}) was estimated using a progressive submaximal protocol on a mechanical exercise bike (Monark® Ergomedic model 828E) with 8-minute duration, with a warm-up period (4 minutes) and a workload calculated based on body weight (4 minutes). The values of blood pressure, heart rate, and subjective perceived exertion were measured at rest and at each minute of the test. The children were instructed to pedal at a speed of 50 RPM, and the bikes were previously calibrated.

The same bikes were used in the four periods. VO_{2max} data are shown in absolute values ($L.min^{-1}$), as well as in values relative to body mass ($mL.kg^{-1}.min^{-1}$), thus allowing for a more accurate comparison between students with different body compositions. To calculate the absolute and relative VO_{2max}, Åstrand's nomogram[17] was used, considering the heart rate in the last minute of the exertion load. All measurements and tests followed the same standardization in all assessed periods.[14] The objectivity and reproducibility of the measurements obtained from a subsample of 30 randomly selected schoolchildren in each evaluation were calculated and used as an internal quality criterion of all measurements and tests. Variations of objectivity and reproducibility were observed over the four time periods analyzed, as follows: body weight, 0.96 and 0.99; height, 0.97 and 0.99; and aerobic power, 0.58 and 0.88, respectively.

Statistical analysis

Descriptive statistics, means, standard deviation, frequency, and percentage were used in the statistical analysis. The variation between 2008/2010 and 1978/1988 was assessed by the delta percent (Δ%). Data distribution was verified by the Kolmogorov-Smirnov test.[18] A comparison among the four cardiorespiratory fitness evaluations was performed by analysis of variance with three factors (gender, nutritional status, and decade), followed by Bonferroni multiple comparison.[18] The calculations were performed using the Statistical Package for the Social Sciences (SPSS), release 18.0, and the level of significance was set at $p < 0.01$.[18]

Results

From a database with over 16,000 evaluations from 1978 to 2011, 1,291 students met the inclusion criteria. In both genders, in the four evaluations performed during the 30-year period with ten-year intervals, the number of schoolchildren with normal weight (n = 789, 61%) was higher than overweight (n = 502). In males, the number of students with normal weight was higher than the number of those with overweight in all evaluations. In females, the same was observed in the evaluations performed in 1998/2000 and 2008/2010 (Fig. 1).

In Table 1, the analysis of variance showed that after three decades, the mean values of anthropometric data were not statistically different in the four evaluations performed during the study period, both in schoolchildren with normal weight and with overweight. When comparing the nutritional status, Table 1 shows that the mean values of height were statistically higher in all evaluations in overweight schoolchildren when compared to those with normal weight. When comparing the nutritional status of male schoolchildren, it was observed that there were significant differences in the evaluations of 1998/2000 and 2008/2010. As for females, there were significant differences in 1988/1990, 1998/2000, and 2008/2010 ($p \leq 0.001$).

Both absolute and relative cardiorespiratory fitness of schoolchildren with normal weight or overweight decreased significantly when comparing the evaluations performed in 2008/2010 with the others. Regarding absolute and relative VO_{2max}, the decrease was greater in schoolchildren with normal weight (23.5% and 25.8%, respectively) than in overweight children (15.2% and 16.2%, respectively). Comparing all analyzed periods, the results of the 2008/2010 evaluation were statistically lower than those observed in other evaluations (Table 2).

While still comparing the 2008/2010 evaluation with the others, there was a significant decrease in the absolute and relative cardiorespiratory fitness values in schoolchildren with normal weight in both genders, and in overweight females (Table 2).

When comparing the nutritional status to absolute cardiorespiratory fitness, the overweight students showed statistically different and higher values only in the evaluation performed in 1998/2000. Regarding the relative cardiorespiratory fitness, overweight schoolchildren had significantly lower values in the four evaluations (Table 2).

Regarding aerobic power ($L.min^{-1}$), no significant difference was observed according to the nutritional status of all evaluations, except in that performed in 1998/2000 (Table 2).

Regarding the relative aerobic power ($mL.kg^{-1}.min^{-1}$), normal weight male schoolchildren had statistically higher values than overweight males in the evaluations performed in 1978/1980 ($p = 0.003$), 1998/2000 ($p = 0.001$), and 2008/2010 ($p \leq 0.001$). There was no statistical difference between nutritional status and relative VO_{2max} in females (Table 2).

When comparing between genders of schoolchildren with normal weight, males presented higher absolute VO_{2max} values than females at the 2008/2010 evaluation, and in all evaluations regarding the relative VO_{2max} values. As for schoolchildren with excess weight, males presented statistically significant higher absolute VO_{2max} values than females only in the 2008/2010 evaluation.

Table 1 Proportion of schoolchildren with normal weight and overweight and comparison of anthropometric variables between genders and nutritional status of schoolchildren in Ilhabela.

	1978/1980	1988/1990	1998/2000	2008/2010	p[a]	Δ%[b]
Normal weight						
f (%)						
Boys	51 (27.2)	110 (35.8)	156 (41.6)	184 (43.8)		
Girls	43 (22.8)	62 (20.2)	92 (24.6)	91 (21.6)		
Total	94 (50.0)	172 (56.0)	248 (66.2)	275 (65.4)		
Body weight						
Boys	31.53 (6.23)	31.41 (4.45)	31.94 (4.70)	31.76 (4.76)	1.00	0.7
Girls	35.42 (9.52)	34.36 (7.25)	34.91 (7.61)	35.70 (7.23)[c]	1.00	0.7
Total	32.41 (0.87)	32.48 (0.54)	33.08 (0.44)	33.03 (0.42)	1.00	1.9
Height						
Boys	138.80 (5.88)	138.83 (7.46)	140.06 (6.82)	139.82 (7.43)	1.00	0.7
Girls	141.31 (6.46)	139.62 (7.80)	141.68 (6.58)	143.42 (8.11)	0.87	1.4
Total	139.37 (0.94)	139.11 (0.58)	140.68 (0.48)	140.98 (0.45)	0.64	1.1
Overweight						
f (%)						
Boys	42 (22.3)	63 (20.5)	56 (14.9)	64 (15.2)		
Girls	52 (27.7)	72 (23.5)	71 (18.9)	82 (19.4)		
Total	94 (50.0)	135 (44.0)	127 (33.8)	146 (34.6)		
Body weight						
Boys	46.02 (9.90)[d]	41.22 (7.74)[d]	46.70 (45.20)[d]	45.20 (7.06)[d]	1.00	-1.7
Girls	38.60 (7.84)	39.57 (9.54)[d]	37.85 (8.38)[c]	38.73 (8.39)[c]	1.00	0.3
Total	40.32 (0.96)[d]	40.09 (0.69)[d]	41.75 (0.63)[d]	41.21 (0.66)[d]	1.00	2.2
Height						
Boys	145.60 (9.21)	141.60 (10.65)	146.76 (8.12)[d]	145.51 (5.40)[d]	1.00	0
Girls	147.18 (7.96)	145.77 (8.51)[d]	146.50 (9.14)[d]	148.40 (7.63)[d]	0.93	0.8
Total	146.83 (1.04)[d]	144.46 (0.74)[d]	146.62 (0.67)[d]	147.30 (0.71)[d]	1.00	0.32

[a] Analysis of variance.
[b] Delta percent.
Multiple comparison Bonferroni test.
[c] $p < 0.01$: for comparisons between males and females.
[d] $p < 0.01$: for comparisons between normal weight and overweight.

Discussion

The current study demonstrated a significant decrease in cardiorespiratory fitness in both genders, in four evaluations performed during a 30-year period with ten-year intervals in the town of Ilhabela, which could not be explained by the nutritional status. This decrease was more significant in schoolchildren with normal weight than overweight.

A literature review showed that in 33 years (1970-2003), cardiorespiratory fitness (VO_{2max}) decreased 0.46% per year in students from 27 countries in the world, values that were lower than those of the present study (0.51%).[19] The findings of the present study corroborate those of others, in which greater decreases in physical activity were more often found in females than in males.[20] Conversely, Tomkinson et al.[21] found a decrease of 0.46% per year in males and 0.41% in females.

Although there are several studies[10,22] in the literature on the secular trend of growth, it is of utmost importance to stress the relevance of studies developed in the same project, with a population living in the same place, using the same methodology and standardized measures.[10,13] Rejman and Matsudo[13] performed a study with schoolchildren from Project Ilhabela and found that in ten years, boys had significantly greater height (3.2 cm). In girls, no difference was observed during the analyzed period; however, there was an increase of 1.4 cm. Using the same method of the present study to control the current nutritional status, Ferrari et al.[10] found changes in adiposity in 20 years (1990-2010); in both genders, the increase was greater among overweight schoolchildren than in those with normal weight.

The huge socioeconomic changes that occurred in Brazil over the past three decades have resulted in the increase in obesity and height, which are approaching the values observed in developed countries.[3] The percentage of Brazilian overweight children has more than tripled (1975-2009), from 9.8% to 33.4%.[23] In this study, body weight was found to be stable during the 30-year period.

Obesity and cardiorespiratory fitness in young people are strongly associated with cardiovascular risk factors.[19] Regardless of the nutritional status, some authors[24,25] found

Table 2 Comparison of cardiorespiratory fitness between genders and nutritional status of schoolchildren in Ilhabela.

	1978/1980	1988/1990	1998/2000	2008/2010	p[a]	Δ%[b]
Normal weight						
VO_{2max} ($L.min^{-1}$)						
Boys	1.57 (0.30)[c]	1.43 (0.32)[c]	1.50 (0.30)[c]	1.26 (0.33)	<0.001	-19.7
Girls	1.36 (0.41)	1.36 (0.10)[c]	1.35 (0.20)[c]	1.10 (0.15)[d]	<0.001	-19.1
Total	1.53 (0.45)[c]	1.40 (0.26)[c]	1.44 (0.21)[c]	1.17 (0.23)	<0.001	-23.5
VO_{2max} ($mL.kg^{-1}.min^{-1}$)						
Boys	50.06 (5.95)[c]	46.01 (9.81)[c]	47.22 (9.38)[c]	38.98 (4.78)	<0.001	-22.1
Girls	36.64 (5.97)[d]	39.81 (4.18)[c,d]	39.51 (5.83)[c,d]	27.15 (4.61)[d]	<0.001	-25.9
Total	47.90 (1.37)[c]	43.88 (0.79)[c]	44.32 (0.65)[c]	35.5 (3.24)	<0.001	-25.8
Overweight						
VO_{2max} ($L.min^{-1}$)						
Boys	1.67 (0.27)	1.63 (0.36)	1.63 (0.33)	1.47 (0.34)	0.08	-12
Girls	1.46 (0.35)[c]	1.44 (0.25)[c]	1.46 (0.19)[c]	1.17 (0.20)[d]	<0.001	-20
Total	1.51 (0.51)[c]	1.49 (0.33)[c]	1.53 (0.30)[c,e]	1.28 (0.35)	<0.001	-15.2
VO_{2max} ($mL.kg^{-1}.min^{-1}$)						
Boys	36.50 (6.10)[e]	40.53 (6.59)	35.63 (5.36)[e]	31.84 (6.37)[e]	0.07	-12.7
Girls	37.15 (3.69)	36.15 (4.93)[c]	39.63 (4.42)[c]	30.42 (3.68)	<0.001	-18
Total	36.98 (1.56)[c,e]	38.23 (1.01)[c,e]	37.84 (0.91)[c,e]	30.96 (4.74)[e]	<0.001	-16.2

[a] Analysis of variance.
[b] Delta percent.
Bonferroni multiple comparison test.
[c] $p < 0.01$: for comparisons between 1978/1980, 1988/1990, and 1998/2000 with 2008/2010.
[d] $p < 0.01$: for comparisons between males and females.
[e] $p < 0.01$: for comparisons between normal weight and overweight.
VO_{2max}, cardiorespiratory fitness.

decreased cardiorespiratory fitness over the years, mainly in boys.[24]

Supporting the present findings, reduced cardiorespiratory fitness was observed not only in obese English schoolchildren, but also in those with normal weight.[4] In contrast with the results found for cardiorespiratory fitness ($L.min^{-1}$), obese students, when undergoing VO_{2max} evaluation through running tests, presented worse physical fitness results than those with normal weight.[26,27] That occurs mostly when obese students exercise where body weight support is necessary, such as running.[7] Some authors[4,26,27] found an inverse association between anthropometry and physical fitness, but it was not possible to establish a cause-effect association. Unfavorable body composition and physical activity have a strong association with risk factors for cardiovascular disease, which may be harmful to public health and increase the risk of premature death.[27]

Considering active transportation to school (walking or cycling) as mild or moderate physical activity, Smpokos et al.[28] found a decrease of the latter (1992/93-2006/07) in schoolchildren in Greece. With the experience of over three decades with Project Ilhabela, the findings of the present study showed considerable decrease in VO_{2max} values, both in obese schoolchildren and in those with normal weight. These results suggest that the decrease in cardiorespiratory fitness and physical activity may be related to sedentary behavior. Thus, the suggested hypothesis is that the decrease in physical activity and the use of active transportation to school[2] could explain the present findings, as active transportation to school increase by five-fold the odds of having a good level of cardiorespiratory fitness.[29]

Supporting the present findings, studies have demonstrated that girls present lower rates of physical activity practice inside or outside school when compared with boys, a well as high rates of physical inactivity.[2,11] Therefore, establishing the prevalence of physical inactivity and identification of risk groups are important to institute intervention strategies.

Despite the importance of a study performed over three decades on an island in a developing country, thus minimizing the rate of migration, which helped to decrease the influence of external factors, the authors believe that the current study has some limitations. Submaximal cardiorespiratory fitness was used in this study. Submaximal tests are suitable for non-hospital environments due to the reduced possibility of cardiorespiratory complications;[30] however, the mean values of data quality in all decades ranged from moderate to high in cardiorespiratory fitness, and it was not assessed whether the decrease in cardiorespiratory fitness was associated with an increased level of inactivity among students. Intervention strategies should be directed not only to overweight children, but also to those with low physical fitness and high sedentary time.

During the 30-year analysis, with evaluations every ten years from 1978/1980, there was a significant decrease in cardiorespiratory fitness among schoolchildren aged 10 to

11 years, of both genders, which could not be explained by the nutritional status. The decline in cardiorespiratory fitness was greater in schoolchildren with normal weight than in those with overweight.

Future studies are necessary to identify the determinant factors in the reduction of cardiorespiratory fitness to associate lifestyle, such as customary physical activity, with cardiorespiratory fitness in schoolchildren of both genders.

Intervention strategies should be directed not only to overweight children, but also those with normal weight and/or with low physical fitness and high sedentary time.

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Conflicts of interest

The authors declare no conflicts of interest.

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