RELATIONSHIP OF PHYSICAL FITNESS AND BODY COMPOSITION IN THE INCIDENCE OF HYPERTENSION AMONG SCHOOL-AGED CHILDREN AND YOUTH IN THE NORTH OF PORTUGAL

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ABSTRACT

The purpose of this study was to analyse the relationship of physical fitness and body composition to blood pressure (BP) in school-aged children and youth from 12 to 18 years old. Ninety-one male and female students were evaluated on the following: systolic blood pressure (SBP), diastolic blood pressure (DBP), body mass index (BMI), waist circumference, body fat percentage, and five independent FITNESSGRAM® physical tests (shuttle-test, curl-ups, push-ups, shoulder-stretch, and sit-and-reach). There were significant associations between shoulder stretch and SBP from 17 to 18 years (p = 0.012), and between BMI and SBP in ages 14 to 18 years ($p < 0.05$). Changes in SBP were related to curl-ups in ages 17 to 18 years (r^2 = 0.37), and to BMI in ages 14 to 16 years (r^2 = 0.29), and 17 to 18 years (r^2 = 0.34). Changes in DBP were related to BMI in ages 14 and 16 years (r^2 = 0.55), and 17 to 18 years (r^2 = 0.22). Physical fitness levels exhibited a minor influence on BP; in contrast, high BMI is consistently associated with high BP in ages 14 through 18 years.

Keywords: Body Mass Index, Hypertension, Physical Fitness, School-Aged Population, FITNESSGRAM®

RESUMO

Este estudo teve como objetivo analisar a relação entre a aptidão física e a composição corporal com a pressão arterial (PA) em crianças e jovens em idade escolar, entre 12 a 18 anos de idade. Noventa e um alunos de ambos os géneros foram avaliados nos parâmetros: pressão arterial sistólica (PAS), pressão arterial diastólica (PAD), índice de massa corporal (IMC), perímetro da cintura, percentagem de gordura corporal, e cinco testes de aptidão física independentes da bateria FITNESSGRAM® (shuttle-test, curl-ups, push-ups, shoulder-stretch, and sit-and-reach). Identificaram-se associações significativas entre o shoulder-stretch e a PAS, entre os 17 e os 18 anos (p = 0.012), e entre o IMC e a PAS, entre os 14 e os 18 anos ($p < 0.05$). Alterações na PAS foram relacionadas com o curl-ups, entre os 17 e os 18 anos (r^2 = 0.37); e com o IMC, entre os 14 e os 16 anos (r^2 = 0.29) e os 17 e os 18 anos (r^2 = 0.34). Alterações na PAD foram relacionadas com o IMC, entre os 14 e os 16 anos (r^2 = 0.55) e entre os 17 e os 18 anos (r^2 = 0.22). Os níveis de aptidão física apresentaram pouca influência na PA; em contraste, um IMC elevado está consistentemente associado com pressão arterial elevada entre os 14 e os 18 anos.

Palavras-chave: Índice de Massa Corporal, Hipertensão, Aptidão Física, População em Idade Escolar, FITNESSGRAM®

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INTRODUCTION

Hypertension remains the most prevalent and preventable cause of cardiovascular disease. Although the prevalence of hypertension during childhood is lower than that seen in adulthood, this condition is now common in both children and adolescents.[1, 2] High blood pressure (BP) levels tends to track from childhood into adulthood,[3] suggesting that prevention and control of BP values in children might be an important strategy for limiting the global disease burden related to hypertension.[4] The development of such a strategy emphasizes the importance of assessing BP and requires the establishment of the links with its associated factors in child and adolescent populations. In children, the diagnosis of hypertension is defined relative to the 95th percentile of the office blood pressure in various strata, which account for sex, age, and body weight.[5] Several factors have been suggested as significant predictors of hypertension in children and adolescents, including the level of education, socioeconomic status, diet, dyslipidemia, inflammation process, poor physical activity, and physical fitness levels.[6, 7] This last one seems to have an important opposite effect. Shook et al.[8] studied the association of fitness level to hypertension incidence in 6278 participants, and after adjusting for age, sex, and examination year, found that both moderate and high fitness levels were associated with lower risk (26% and 42%, respectively) for developing hypertension. In contrast, low levels of physical fitness are associated with an increased risk of being hypertensive.[9–11]

However, this proposed association is complex because fitness level changes are often linked to body mass variations, which are also implicated in the development of hypertension. Data from the Cooper Center Longitudinal Study[12] suggest that BMI is a more important predictive factor of high BP than is fitness.

As one of the primary environments that children experience, schools have attracted attention for their potential role in the promotion of several healthy behaviors. In fact, from an ecological model perspective, schools are a key setting to promote physical activity and fitness in children and may represent an important factor in the prevention of childhood hypertension in particular, considering that children spend as much as 60% to 70% of their waking hours at school.[13] Therefore, the purpose of this study was to analyse the relationship between physical fitness and body composition levels and blood pressure variations among public school-aged children and youth in the North of Portugal.

METHODS

Participants

Ninety-one children and young students (between 12 and 18 years of age; 49 males and 42 females) from two schools in the North of Portugal voluntarily participated in a cross-sectional study. None of the students had a previous history of sports training, and the only supervised physical activity consisted of physical education classes twice each week (each class was 60 minutes in duration). Both verbal and written consents were obtained from each school's authorities and all participants' parents, after they were informed about the objectives, procedures, and potential discomfort. The study was approved by the University of Trás-os-Montes e Alto Douro review board for human subjects, according to the Helsinki Declaration. All institutional and governmental regulations pertaining to the ethical use of human volunteers were followed during this research.

The students were stratified into three different age–school groups as follows: (I) a 12- and 13-year-old group (G12–13, n = 39, 12.7 ± 0.4 years, BMI = 20.4 ± 2.4 kg/m^2); (II) a 14-to-16-year-old group (G14–16, n = 25, 14.9 ± 0.8 years, BMI = 22.3 ± 3.4 kg/m^2); and (III) a 17- and 18-year-old group (G17–18, n = 27, 17.8 ± 0.4 years, BMI = 23.0 ± 3.1 kg/m^2).

Measurements

Blood pressure. Measurements were performed in a quiet and temperate room by trained clinical officers. Following five minutes of sitting at rest, systolic BP (SBP) and diastolic BP (DBP) were measured three times, with one minute between readings, using a portable sphygmomanometer (Omron, 705IT, Omron Healthcare Europe BV, Hoofddorp, The Netherlands). If the BP measurements differed by more than 5 mmHg, additional readings were obtained after another five minutes of quiet sitting. The mean of three consecutive readings within 5 mmHg of each other was used as the value for SBP and DBP. All measures were taken by the same technician with a standard, appropriately sized cuff suitable for age and arm length and width of each participant, according to the National High Blood Pressure Education Program.[5] According to the criteria set forth in the 2004 task force report on HBP in children and adolescents, hypertension in this study was defined as an average SBP or DBP ≥ 95th percentile for age, sex, and height measured on at least three separate occasions, and prehypertension was defined as an average SBP or DBP ≥ 90th percentile but less than the 95th percentile.[5]

Body composition. BMI for each participant was calculated with height (cm) and weight (kg) measured on a standard scale with a stadiometer (SECA 770, Seca Corporation, Hamburg, Germany) following standard procedures. Normal, overweight, and obesity were defined respectively as a BMI less than the 85th percentile, between the 85th and 94th percentiles, and of at least the 95th percentile of the United States reference data, which are often used to define excess body weight in children.[14] Waist circumference was measured with a commercial tape measure to the nearest 0.1 cm using standard procedures.[15] Participants' measurements were reported as a binary "meets" or ''does not meet,'' according to the cut-off values suggested by Taylor et al. [16] Percentage of fat mass (%FM) was assessed using the equation developed and validated by Slaughter et al.[17] This equation uses the triceps (T) and gastrocnemius (G) skinfolds [%FM = 0,735(T+G)+1]. The measurement was performed with skinfold calipers (Slim Guide, Creative Health Products, Plymouth, MI, US), according to the procedures described by Harrison et al.[18] Participants were classified into "slimness," "normal," and "excess fat," according to the FITNESSGRAM® standards for the Healthy Fitness Zones.[19]

Physical fitness. Physical fitness was measured by five independent fitness tests using FITNESSGRAM® (The Cooper Institute, Dallas, TX, US) as follows: (1) aerobic capacity, measured by the shuttle-test; (2) abdominal strength and endurance, measured by curl-ups; (3) upper-body strength and endurance, measured by push-ups; (4) upper-body flexibility, measured by shoulder-stretch; and (5) lower-body flexibility, measured by the sit-and-reach test. Each test was performed according to the FITNESSGRAM® manual instructions.[19] FITNESSGRAM® is a criterion-based rather than a norm-based assessment of fitness. The result of each test is not compared using percentile ranks to other results from the same cohort; it is compared to a range of acceptable values, based on established health standards for the age and gender of the individual.

FITNESSGRAM®'s criterion-based system reports a binary "meets" or "does not meet" result for each test, based on the Healthy Fitness Zone for the individual's gender and age.

Statistical analysis

Normal distribution was tested with the Shapiro-Wilk test, and the skewness and kurtosis indices were analyzed. The chi-square test (X^2) was applied to test the independence between the variables of physical fitness and body composition, with high BP in both groups. Stepwise multiple linear regression analyses were performed to determine the percentage of the variability between physical fitness, body composition, and high BP. All data were analyzed using the statistical software IBM SPSS Statistics for Macintosh, version 19.0.0 (SPSS Inc., Chicago, IL, US), and the level of statistical significance was set at $p < 0.05$.

RESULTS

Figures 1 and 2 show study sample percentages distribution by BP and body composition categories in the different groups. Figure 3 shows study sample percentage distribution by physical fitness status in the different groups.

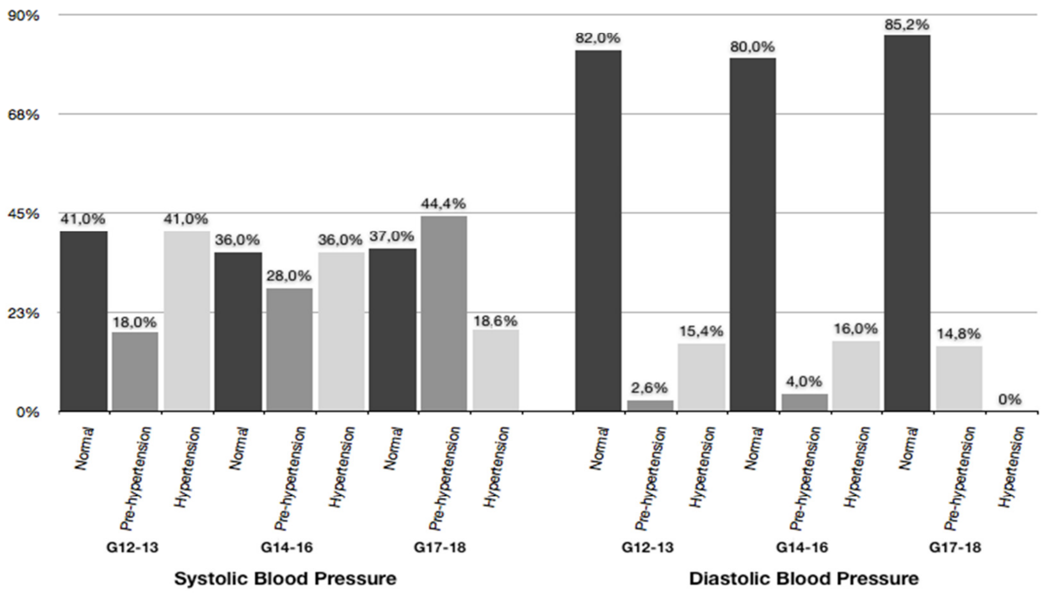

Figure 1. Study sample percentage distribution by blood pressure categories in the age 12 to 13 years group (G12–13), the age 14 to 16 years group (G14–16), and the age 17 to 18 years group (G17–18).

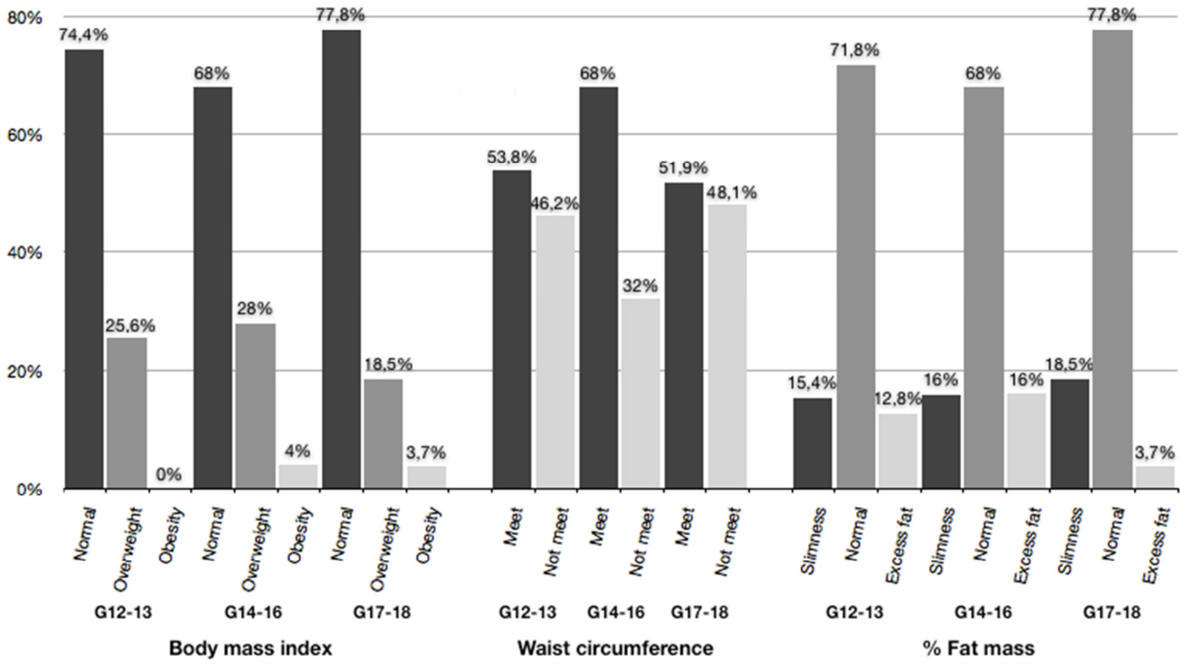

Figure 2. Study sample percentage distribution by body composition categories in the age 12 to 13 years group (G12–13), the age 14 to 16 years group (G14–16), and the age 17 to 18 years group (G17–18).

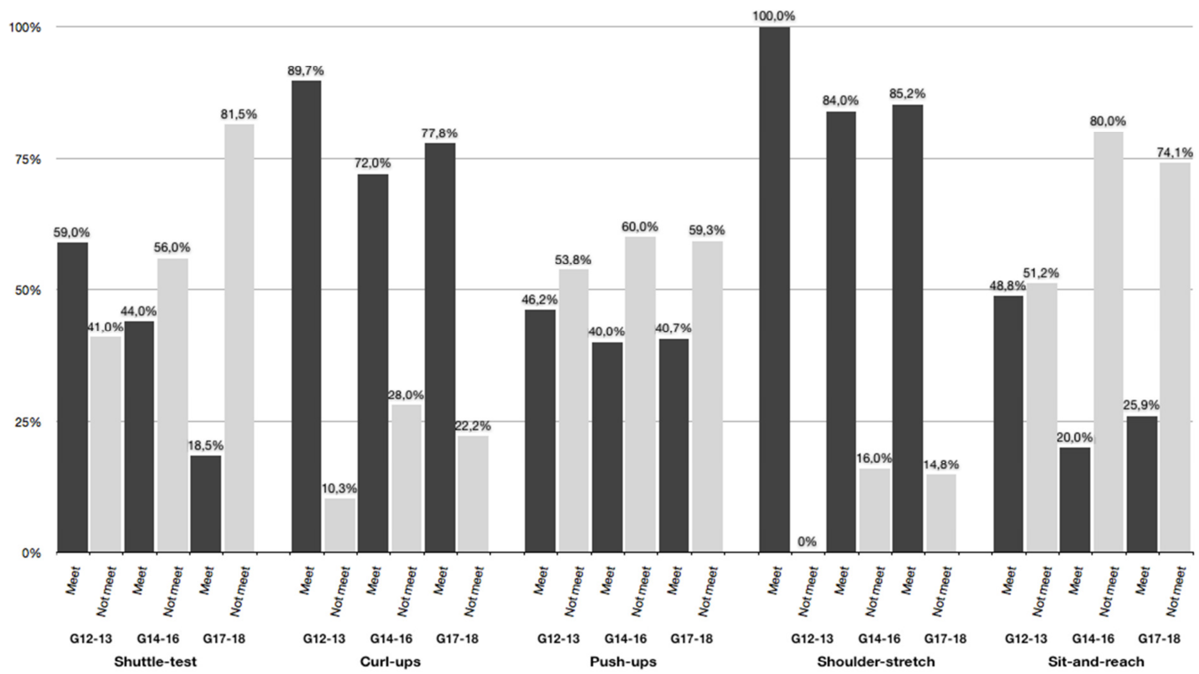

Figure 3. Study sample percentage distribution by physical fitness status in the age 12 to 13 years group (G12–13), the age 14 to 16 years group (G14–16), and the age 17 to 18 years group (G17–18).

For the physical fitness tests, there was a significant association only between shoulder-stretch and SBP in G17–18 (X^2 = 10.23, *p* = 0.012). For body composition, there was a significant association between BMI and SBP in G14–16 (X^2 = 14.03, *p* = 0.001) and G17–18 (X^2 = 9.33, *p* = 0.036). In addition, there was a significant association between waist circumference and SBP in G14–16 (X^2 = 7.79, *p* = 0.025). Table I shows a summary of X^2 test results between physical fitness, body composition, and BP in the different groups.

Table 1. Chi-square (X^2) test results between physical fitness, body composition, and blood pressure in the age 12 to 13 years group (G12–13), the age 14 to 16 years group (G14–16), and the age 17 to 18 years group (G17–18).

		Systolic blood pressure		Diastolic blood pressure	
		X^2	*p*	X^2	*p*
Shuttle-test	G12-13	0.55	0.832	1.80	0.489
	G14-16	0.90	0.875	1.66	0.613
	G17-18	0.82	0.814	1.07	0.561
Curl-ups	G12-13	0.49	1.000	0.41	1.000
	G14-16	0.28	1.000	4.17	0.196
	G17-18	2.60	0.289	0.02	1.000
Push-ups	G12-13	2.43	0.326	1.95	0.387
	G14-16	1.46	0.596	1.25	0.772
	G17-18	1.32	0.461	0.48	0.624
Shoulder-stretch	G12-13	(constant)	-	(constant)	-
	G14-16	3.51	0.286	4.17	0.259
	G17-18	10.23	0.012	0.82	0.596
Sit-and-reach	G12-13	0.37	0.916	0.98	1.000
	G14-16	0.20	1.000	0.31	1.000
	G17-18	2.96	0.275	1.64	0.318
Body mass index	G12-13	1.49	0.555	0.70	0.748
	G14-16	14.03	0.001	8.19	0.098
	G17-18	9.33	0.036	0.20	1.000
Waist circumference	G12-13	0.16	1.000	1.44	0.663
	G14-16	7.79	0.025	2.25	0.496
	G17-18	3.10	0.286	1.01	0.596
% Fat Mass	G12-13	5.44	0.258	0.49	1.000
	G14-16	3.85	0.508	5.26	0.376
	G17-18	3.32	0.640	0.29	1.000

The only predictors accepted in the model for changes in SBP were induced by the BMI levels in G14–16 (r^2 = 0.29), and by curl-up performance and BMI levels in G17–18 (r^2 = 0.34). Changes in DBP were induced by BMI and waist circumference levels in G14–16 (r^2 = 0.55) and by BMI levels in G17–18 (r^2 = 0.22). Table II shows the summary of the Stepwise multiple linear regression analyses between physical fitness, body composition, and BP in the different groups.

Table 2. Stepwise multiple linear regression analyses between physical fitness, body composition, and blood pressure in the age 12 to 13 years group (G12–13), the age 14 to 16 years group (G14–16), and the age 17 to 18 years group (G17–18).

		Systolic blood pressure			Diastolic blood pressure		
		ß	t	*p*	ß	t	*p*
Shuttle-test	G12-13	.015	0.090	0.929	-0.172	-1.062	0.295
	G14-16	-0.030	-0.152	0.880	-0.142	-0.569	0.576
	G17-18	-0.038	-0.206	0.839	-0.211	-1.162	0.257
Curl-ups	G12-13	0.022	0.132	0.896	-0.138	-0.848	0.402
	G14-16	-0.242	-1.367	0.185	0.009	0.040	0.969
	G17-18	0.253	2.096	0.047	-0.285	-1.485	0.151
Push-ups	G12-13	0.120	0.732	0.469	0.021	0.127	0.900
	G14-16	-0.102	-0.565	0.578	-0.428	-2.084	0.051
	G17-18	0.185	0.969	0.343	-0.292	-1.612	0.121
Shoulder-stretch	G12-13	-0.154	-0.948	0.349	0.041	0.251	0.803
	G14-16	-0.173	-0.868	0.395	-0.274	-1.677	0.110
	G17-18	-0.075	-0.395	0.697	0.271	1.400	0.175
Sit-and-reach	G12-13	0.135	0.829	0.412	-0.109	-0.665	0.510
	G14-16	-0.282	-1.644	0.114	-0.180	-1.108	0.282
	G17-18	-0.062	-0.330	0.744	0.670	1.862	0.075
Body mass index	G12-13	0.055	0.336	0.739	-0.104	-0.635	0.530
	G14-16	1.265	3.049	0.006	3.368	3.786	0.001
	G17-18	1.493	3.380	0.002	1.288	2.379	0.026
Waist circumference	G12-13	-0.094	-0.576	0.568	-0.119	-0.730	0.470
	G14-16	-0.155	-0.440	0.665	-1.498	-3.832	0.001
	G17-18	-0.175	-0.554	0.554	-0.366	-1.082	0.291
% Fat Mass	G12-13	0.079	0.480	0.634	0.100	0.614	0.543
	G14-16	-0.179	-0.760	0.456	0.583	1.747	0.096
	G17-18	-0.204	-1.153	0.261	0.236	1.248	0.225

DISCUSSION

The main finding of the present study adds to other evidence that an association does in fact exist between BMI and hypertension in school-aged adolescents from 14 to 18 years old. In contrast, we found few associations between physical fitness and hypertension, and those are conflicting.

These present results confirm prior reports stating an overall association, strongest for BMI and hypertension, among school-aged youth from 12 to 18 years old.[7, 20, 21] This result also demonstrates that each additional unit of BMI is associated with an increase of both SBP (r^2 = 0.29 for G14–16 and r^2 = 0.34 for G17–18) and DBP (r^2 = 0.55 for G14–16 and r^2 = 0.22 for G17–18).

The present results show a high prevalence of hypertension (BP > 95th percentile) and pre-hypertension (BP 90th to < 95th percentile) in schoolchildren and adolescents, particularly high levels of SBP (41%, 36%, and 18.6% for G12–13, G14–16, and G17–18, respectively; see Figure 1). Although the DBP normal values clearly were high in all groups (> 80%), given the early stage of their prevalence, these results are very disturbing, even taking into account the small sample size. High BP in children tends to track from childhood into adulthood, as previously reported [3]. In recent studies that included mostly minority schoolchildren, the prevalence of BP > 95th percentile was 16% to 17%,[1, 22] with or without DBP > 95th percentile. The results of these studies suggest that BP > 95th percentile is not rare in children.

Since none of the students had a previous history of sports training and the only supervised physical activity consisted of physical education classes (twice per week, 60 minutes each), we expected to find more students with overweight and obesity. Most students had a normal or lower body-fat percentage (see Figure 2). These results can be explained by the growth phase of these students; their ages are characteristic of high metabolic and anabolic influence.[23] However, a high percentage of students did not meet the desirable waist circumference (46.2%, 32%, and 48.1%, for G12–13, G14–16, and G17–18, respectively, see Figure 2). We also found a positive association between waist circumference and SBP in youth ages 14 to 16 (*p* = 0.012). This association means that higher abdominal fat is related to hypertension, as has been reported in other studies.[24, 25] Yet, surprisingly, we identified a negative relationship between waist circumference and DPB for the same ages. However, it should be noted once more that 80% of the participants in this group showed normal values of DBP. Further, considering the waist circumference variable, this group showed the highest normal values (68%; see Figure 2).

The youngest group (12–13 years) was clearly more fit compared to others, particularly in the areas of flexibility and aerobic capacity (see Figure 3). All groups had good muscular resistance but low muscle strength. This could be due to the complexity of both exercises. Curl-ups seem easiest to perform, since they involve raising the trunk against gravity, while push-ups, in addition to gravity, are highly dependent on hand position and palmar pressure distribution.[26, 27] Furthermore, push-ups exhibit high-to-very-high activity from the rotator cuff, deltoids, and scapular muscles, which results in high shoulder-joint stress.[28] We found few associations between physical fitness and hypertension, but we did find a positive association between shoulder-stretch and SBP in youth ages 17 to 18 years ($p = 0.012$). Also in this age group, we found a positive relationship between curl-ups and SBP ($r^2 = 0.37$). This was an unexpected result because these two tests were also those which had, by far, the best results in all groups (see Figure 3). This finding is related to factors that need further research in the future. We expect a greater influence of physical fitness levels on BP, since low levels of physical fitness are significantly associated with the development of hypertension, as reported earlier.[8, 9] The absence of statistical significance in physical fitness implies that there is no linear association between these variables and the SBP and DBP values. The limited association between physical fitness and hypertension, if confirmed, has profound implications for health promotion in schools, suggesting a need for more aggressive strategies to promote fitness and weight control. For physical education and general education practitioners, the potential impact of physical fitness on hypertension prevention should be considered for future studies.

These findings show the need to encourage health care providers to screen children for hypertension or, ideally, to include BP measurement in the child's routine physical exam, especially for children and youth who are overweight. Thus, BP monitoring and early diagnosis of hypertension in children is one of the best strategies for the prevention of chronic diseases in adulthood.[22]

CONCLUSION

In conclusion, physical fitness levels exhibited a minor influence on BP. In contrast, a high BMI is consistently associated with high BP, particularly SBP in ages 14 to 18 years old. The present results suggest that individuals between 12 and 18 years of age with low levels of physical activity are more likely to suffer from prehypertension and hypertension, particularly if they are overweight or obese.

Finally, major efforts should be made to sustain an effective physical education curriculum during the key period of adolescence.

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