Original Article

Blood Pressure Response to Physical Exertion in Adolescents: Influence of Overweight and Obesity

Luciana Carletti[1], Anabel Nunes Rodrigues[2], Anselmo José Perez[1], Dalton Valentim Vassallo[1]
Universidade Federal do Espírito Santo (UFES)[1], Faculdade Salesiana de Vitória[2], Vitória, ES - Brazil

Summary

Background: The acute blood pressure response to physical exertion has been used as an indicator of the risk of developing hypertension. The factors associated with this response need to be clarified for timely intervention in preventing hypertensive disease.

Objective: To describe the response of cardiovascular variables to acute physical exertion in overweight adolescents using cardiopulmonary exercise testing.

Methods: The sample consisted of 104 adolescents (56 boys and 48 girls), divided into two groups: the obese/overweight group (OOG) and the eutrophic group (EG). The following variables were measured: anthropometric (weight, height, and BMI), body composition (skin fold thickness), as well as hemodynamic variables such as systolic arterial pressure (SAP), diastolic arterial pressure (DAP), and heart rate (HR), at rest and at maximal physical exertion during the cardiopulmonary test.

Results: In the male group, the greatest values of systolic arterial pressure at rest were recorded in the OOG as compared to the EG (113 ± 13 *vs* 106 ± 8 mmHg; p = 0.009), pre-exertion SAP (120 ± 14 *vs* 109 ± 10 mmHg; p = 0.003), and SAP during maximal exertion conditions (156 ± 20 *vs* 146 ± 14 mmHg; p = 0.03). In the female group, only pre-exertion SAP was higher in the overweight group as compared to the eutrophic girls (114 ± 11 *vs* 106 ± 10 mmHg; p = 0.009).

Conclusion: The response of arterial blood pressure during physical exercise was most exacerbated in obese adolescents as compared to eutrophic teens, suggesting greater reactivity to physical exertion. (Arq Bras Cardiol 2008;91(1):24-28)

Key words: Blood pressure; adolescent; exertion; obesity; overweight; calorimetry.

Introduction

The hemodynamic response of adults to exercise stress testing has been extensively studied, and the results underline the relationship between the hyperreactive performance of blood pressure and the development of hypertension[1-4], emphasizing the role of this variable in the stratification of cardiovascular risk[5].

Over the past decades, physiological responses to physical exertion have been closely studied in the pediatric[6] and teen[7] populations for a better understanding of the physiopathologic mechanisms involved. After 12 years of follow-up, preliminary findings point to a consistent relationship between arterial blood pressure values measured right after physical exertion and measured at rest[4]. In children and adolescents, the long follow-up period makes it difficult to establish the predictive value of such a response, and this can lead to inconclusive results[8].

Mailing address: Luciana Carletti •
Rua Itaquari, 300, Itapoã, 29.101-902, Vila Velha, ES - Brazil
E-mail: lcarletti@terra.com.br
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The factors that seem to influence arterial pressure response to physical exertion in children and adolescents include resting arterial blood pressure[9], age and gender[10], ethnicity[11,12], obesity[13], dyslipidemias[14], genetics[15], physical fitness[16] and family history of hypertension[17].

Among the abovementioned factors, evidence indicates that obesity stands out as a major factor in the arterial pressure response to physical exertion[13,18], and findings of locally conducted studies have helped elucidate this behavior in obese adolescents during exercise stress testing[18]. Nevertheless, there are limitations as to the identification of cardiorespiratory fitness (VO_{2max}) reported, since the papers published were based on the results of conventional exercise stress testing, which could restrict the interpretation of the actual value of VO_{2max} obtained. Knowing that a poorer cardiorespiratory condition is expected in obese individuals[13], and it is also an important variable in the interpretation of pressure responses[16] to physical exertion, it is believed that this factor should be carefully measured through cardiopulmonary testing[19].

Therefore, the aim of this study was to analyze the hemodynamic response to physical exertion in a group of overweight/obese schoolchildren using cardiopulmonary testing.

Methodology

The sample consisted of 104 junior high school students (56 boys and 48 girls), 11 to 15 years of age, attending both government and private schools in the city of Vitória, state of Espírito Santo. For sample calculation purposes, a 95% confidence level and a 90% confidence interval were adopted, using Willett's equation (1998) for independent samples[20]. The minimum number of participants included in the calculation was 20 students, considering that a difference of at least 10 mmHg in blood pressure values was expected between the groups.

The students were invited to enroll in the study and, along with their parents/guardians, were informed about the methods of the study. Participation in the trial was formalized by signing informed consent forms. The Ethics Committee of the Faculdade Salesiana de Vitória, ES, approved this survey.

The hemodynamic responses of the groups were analyzed as to body composition. For this reason, participants were divided into two groups: the overweight and obese group (OOG), consisting of individuals classified as being over normal body weight according to the criteria detailed below; and the eutrophic group (EG), consisting of individuals classified as being within a healthy weight range.

A complete clinical history was taken of all the adolescents, including a 12-lead resting electrocardiogram (ECG) and clinical assessment by a cardiologist to investigate abnormalities which could preclude participation in the cardiopulmonary test, as well as the use of medications that could interfere in blood pressure behavior (exclusion criterion).

Body weight was measured to the nearest 0.1 kg using an electronic RW200 model Welmy scale, with 200kg maximum capacity. Individuals were weighed wearing as little clothing as possible. Height measurement was performed with a wooden stadiometer (Seca, 206 model), with a maximum length of 220 cm. The Body Mass Index (BMI) was calculated, and the cut-off values needed to define normal weight, overweight, and obesity were based on a study that used international and Brazilian samples[21]. Considering the existing divergence in literature on the use of the BMI to identify obesity and overweight[22], we also included skinfold measurements to provide additional information for our analyses.

A Cescorf skinfold caliper (plicometer) was used to measure subcutaneous fat tissue to the nearest 0.1 mm. Three alternate measurements were made of each skinfold, and the mean value was used. Next, we used the ratio between the triceps and subscapular (T/SR) skinfolds to identify body fat distribution[23,24].

In the study we used the consensus on methodological aspects of blood pressure in children established by the IV Brazilian Guidelines on Arterial Hypertension[25]. Participants were evaluated on at least two consecutive days in a laboratory setting, after having remained seated for 10 minutes in a quiet environment. The mean value was calculated for the systolic and diastolic measurements obtained on both days to establish the values of arterial pressure. A properly calibrated mercury sphygmomanometer (Wan Med) was used to take arterial pressure readings, and the cuff size complied with the abovementioned guideline[22]. Normal values of arterial pressure were considered as those below the 90th percentile for age and height[25].

The maximal oxygen consumption (VO_{2max}) recorded during ergospirometry (cardiopulmonary test) and the maximal ventilation (VE_{max}) were used to obtain an indicator of the physical fitness level of each group. To analyze gases during the cardiopulmonary test, a MedGraphics Corporation (MGC) Cardio2 ergospirometer was used, consisting of a closed-circuit calorimeter. The protocol adopted for the test has been previously described in literature[19].

Before the date set for the cardiopulmonary test, the students visited the laboratory in order to be familiar with the surroundings and be informed about the procedures to be performed.

Before starting the test, all subjects lay down for 5 minutes in a quiet environment, at a room temperature of approximately 22º C, and then the electrical activity of the heart was recorded (resting ECG). The heart rate obtained was considered as the resting heart rate (RHR).

The testing facility was equipped with devices and drugs for emergency medical care. Tests were performed under the supervision of a cardiologist. Subjects were then taken to the ergometric treadmill (Inbrasport Super ATL) and informed about the phases of the test and criteria for interruption. Next, a sphygmomanometer cuff was attached to the arm for blood pressure readings during the test:

• The readings were taken immediately before beginning exercise (right after the preparation for the test),

• After 2 minutes of exercise, known as the submaximal arterial pressure (~ 30% VO_{2max}),

• And at the end of the test, the maximal arterial pressure (100% VO_{2max}).

After approximately two minutes of rest with the patient standing, while electrocardiographic and ventilatory records were obtained (pre-effort phase), the test was started. During testing, the students were monitored via 12-lead ECG for cardiac response and heart rate during exertion.

In this study, a ramp protocol was adopted which consisted of increments according to the predicted oxygen consumption in metabolic equivalents (MET) compared to the oxygen consumption measured.The test was interrupted whenever the subjects signaled (through pre-set gestures) fatigue or any other discomfort which could preclude the continuation of the test. The mean duration of the test was 9 minutes. To check whether the VO_2 recorded was at its maximal level, the following criteria were used[26]: a) Inability to continue exercising; b) Respiratory Exchange Rate (RER) ≥1.0; c) HR_{max} obtained ≥ 90% of the estimated HR; VO_{2max} obtained ≥ 85% of the predicted value.

Student's t test was used to analyze the data collected for the independent samples to compare the two groups as to resting and exercise pressure averages, anthropometric characteristics, metabolic parameters, and physical fitness. Whenever necessary, the ANCOVA test was used to correct confounding variables. *P* values ≤ 0.05 were considered statistically significant.

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Results

The anthropometric, hemodynamic, and physical fitness characteristics of the sample are displayed according to gender on Tables 1 and 2, respectively for girls and boys, showing the total number of individuals in the sample by their classification as overweight and obese (OOG) and eutrophic (EG).

In the female group, a statistical difference was observed only in the anthropometric variables (weight, height, BMI, and T/SR) when both groups were compared (Table 1). In the male group, besides the differences in anthropometric variables, greater values of systolic arterial pressure were observed in the OOG (Table 2), when compared to the EG (113 ± 13 mmHg *vs* 106 ± 8 mmHg; $p = 0.009$).

Table 1 - Anthropometric and hemodynamic characteristics of the female overweight/obese (OOG) *vs* eutrophic (EG) groups.

	OOG Girls	EG Girls	p
N (total)	24	24	-
Age	12.1 ± 1.3	12.0 ± 1.5	0.86
Weight (kg)	59.3 ± 12.9	38.8 ± 9.3**	<0.0001
Height (m)	1.53 ± 0.09	1.46 ± 0.10*	0.02
BMI (kg/sq^2)	25.2 ± 3.8	17.9 ± 2.3**	<0.0001
T/SR (mm)	0.85 ± 0.19	1.43 ± 0.40**	<0.0001
Resting SAP (mmHg)	114 ± 12	108 ± 10	0.07
Resting DAP (mmHg)	66 ± 6	67 ± 8	0.51
Resting MAP (mmHg)	82 ± 7	81 ± 8	0.67
HR (bpm)	84 ± 10	87 ± 9	0.34

*Student's T test for independent samples, ** p≤ 0.01 and * p ≤ 0.05. Average differences between the overweight/obese and eutrophic groups. BMI - body mass index (weight/square height); T/SR - triceps/subscapular ratio; SAP - systolic arterial pressure; DAP - diastolic arterial pressure; MAP - mean arterial pressure; HR - heart rate.*

Table 2 - Anthropometric and hemodynamic characteristics of the male overweight/ obese (OOG) vs. eutrophic (EG) groups.

	OOG Boys	EG Boys	p
N (total)	28	28	-
Age	12.8 ± 1.51	12.1 ± 1.3	0.08
Weight (Kg)	60.7 ± 12.5	38.2 ± 11.0**	<0.0001
Height (m)	1.57 ± 0.09	1.49 ± 0.13**	0.008
BMI (Kg/m^2)	24.3 ± 2.9	16.9 ± 2.3**	<0.0001
T/SR (mm)	0.93 ± 0.32	1.43 ± 0.40**	<0.0001
Resting SAP (mmHg)	113 ± 13	106 ± 8**	0.009
Resting DAP (mmHg)	64 ± 6	65 ± 7	0.53
Resting MAP (mmHg)	81 ± 7	79 ± 6	0.34
HR (bpm)	76 ± 8	78 ± 10	0.51

*Student's T test for independent samples, ** p ≤ 0.01. Average differences between the overweight/obese and eutrophic groups. BMI - body mass index (weight/square height); T/SR - triceps/subscapular ratio; SAP - systolic arterial pressure; DAP - diastolic arterial pressure; MAP - mean arterial pressure; HR - heart rate.*

The cardiopulmonary test applied proved reliable for identifying cardiorespiratory fitness, showing a mean RER value of 1.05 ± 0.07. Therefore, it was observed that 93% of the girls and 87% of the boys reached $VO_{2max,}$ according to the criteria established in this study.

During the test (Table 3), the pre-exercise SAP in overweight boys (120 ± 14 *vs* 109 ± 10 mmHg, $p = 0.003$) and the SAP at the maximal overload were greater than that of the participants of the eutrophic group (156 ± 20 *vs* 146 ± 14 mmHg, $p = 0.03$), reflecting a greater pre-exercise MAP (86 ± 10 *vs* 81 ± 7 mmHg, $p = 0.04$). The VO_{2max} was superior in the EG as compared to the OOG (42.6 ± 6.6 *vs* 36.24 ± 7.2 ml.kg^{-1}.min^{-1}), showing that participants in this group were more physically fit. However, the hemodynamic differences were confirmed even after the adjustment for height and VO_{2max} through covariance analysis (Table 4).

Table 3 - Hemodynamic and physical fitness parameters on progressive exertion recorded for the female overweight/obese vs. eutrophic groups.

	OOG Girls	EG Girls	p
Pre-exercise SAP (mmHg)	114 ± 11	106 ± 10**	0.009
SAP 100% VO_{2max}	143 ± 11	138 ± 13	0.16
Pre-exercise DAP (mmHg)	67 ± 8	65 ± 7	0.46
DAP 100% VO_{2max}	53 ± 6	55 ± 6	0.22
Pre-exercise MAP (mmHg)	83 ± 8	79 ± 7	0.09
MAP 100% VO_{2max} .	83 ± 7	83 ± 8	0.92
VO_{2max} (ml.kg.$^{-1}$.min^{-1})	33.35 ± 5.3	36.73 ± 7.12	0.07
HR 100% VO_{2max}	197 ± 12	194 ± 16	0.52

*Student's T test for independent samples, ** p≤ 0.01. Average differences between the overweight/obese and eutrophic groups. BMI – body mass index (weight/square height); T/SR – triceps/subscapular ratio; SAP – systolic arterial pressure; DAP – diastolic arterial pressure; MAP – mean arterial pressure; HR – heart rate.*

Table 4 - Hemodynamic and physical fitness parameters on progressive exertion recorded for the male overweight/obese vs. eutrophic groups.

	OOG Boys	EG Boys	p
Pre-exercise SAP (mmHg)	120 ± 14	109 ± 10**	0.003
SAP 100% VO_{2max}	156 ± 20	146 ± 14*	0.03
Pre-exercise DAP (mmHg)	69 ± 9	67 ± 7	0.38
DAP 100% VO_{2max}	57 ± 9	56 ± 7	0.74
Pre-exercise MAP (mmHg)	86 ± 10	81 ± 7*	0.04
MAP 100% VO_{2max} .	90 ± 10	86 ± 8	0.10
VO_{2max} (ml.kg.$^{-1}$.min^{-1})	36.24 ± 7.2	42.6 ± 6.6**	0.001
HR 100% VO_{2max}	195 ± 12	195 ± 13	0.97

*Student's T test for independent samples, ** p≤ 0.01 and * p ≤ 0.05. Average differences between the overweight/obese and eutrophic groups. BMI - body mass index (weight/square height); T/SR - triceps/subscapular ratio; SAP - systolic arterial pressure; DAP - diastolic arterial pressure; MAP - mean arterial pressure; HR - heart rate.*

Table 5 - **COVARIANCE analysis of the male overweight/obese vs. eutrophic groups. Adjustment for height and VO_2max.**

	p
Resting SAP	0.02*
Pre-exercise SAP	0.0002**
SAP 100% VO_{2max}	0.005**

*COVARIANCE Analysis, * p ≤ 0,05; ** p ≤ 0,01 - differences between the averages recorded for the overweight/obese* vs *eutrophic groups. SAP – systolic arterial pressure; VO_{2max} – maximal oxygen consumption expressed in $mL.Kg^{-1}.min^{-1}$.*

In the group of girls, no marked difference was observed between the OOG and the EG as to the hemodynamic variables (Table 5). Only the pre-exercise SAP was greater in the overweight group as compared to the eutrophic girls (114 ± 11 *vs* 106 ± 10 mmHg, $p = 0.009$), but this difference did not persist after adjustment for height.

Discussion

Our aim was to analyze the influence of obesity or overweight on the hemodynamic response to physical exertion in a group of healthy and normotensive adolescents. The relevance of this issue is the possibility of early identification of abnormalities in hemodynamic parameters according to the presence of this risk factor, which might contribute to establishing preventive measures during childhood and adolescence.

The individuals studied in this survey who were overweight or obese had a lower level of physical fitness, as had been previously described in literature[20,26-28]. It is interesting to point out that in this study the identification of major hemodynamic abnormalities was only possible in the group of male obese subjects who showed greater cardiovascular demand in the resting and maximal effort phases. These findings deserve further investigation in order to clarify the prognostic importance of the maximal cardiopulmonary exertion test (direct measurement) performed in adolescents to predict future hypertension. Previous data show that SAP at submaximal exertion has a predictive value of 89.7% for detecting arterial hypertension[11].

At maximal intensity (100% VO_2 max), SAP values were greater among the obese adolescents. These hemodynamic changes show that obese subjects have greater cardiac overloads at maximal exertion, concurring with the information that there is a significant association between BMI and SAP at maximal exertion[11]. This is supposedly related to exacerbated central sympathetic activity that contributes primarily in the maximal intensity of exercise when the mechanisms of metabolic and mechanical feedback of active muscles and joints trigger a significant increase of the sympathetic response[29].

The mechanisms proposed to correlate obesity and hypertension allude to the explanation of cardiovascular overload resulting from increased body mass, which would cause increased blood volume and subcutaneous blood vessel tension[27], and metabolic dysfunction caused by the increased fat tissue mass, especially central or visceral fat, raising insulin resistance[28,30]. Evidence of these dysfunctions from obesity is also observed in children and adolescents[31-34].

In this study, the concentration of circulating substances during exercise was not measured to confirm the mechanisms involved in these findings. However, it was observed that adiposity was located mostly in the central region of the body in the overweight individuals, as assessed by the triceps/subscapular ratio (T/SR).

The findings in this study show that the response of arterial blood pressure to exercise was most exacerbated in obese male adolescents as compared to the eutrophic teens, suggesting greater reactivity to physical exertion. The presence of centrally localized obesity (T/SR) was also noted, suggesting that the mechanisms involved in this feature of exacerbated response are probably related to the metabolic and autonomic abnormalities that usually precede the establishment of arterial hypertension.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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There were no external funding sources for this study.

Study Association

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