Arterial Blood Pressure in Adolescents During Exercise Stress Testing

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Summary

Objective: Describe arterial blood pressure response in adolescents undergoing exercise stress testing.

Methods: This was a cross-sectional study conducted with 218 adolescents (131 of whom were males), aged between 10 to 19 years, undergoing exercise stress testing. Maximum heart rate, total exercise time, maximum oxygen uptake, systolic blood pressure (SBP) and diastolic (DBP) at rest, during maximal physical exertion and at six minutes of recovery were measured.

Results: At rest, SBP values were greater in males and no difference was found in DBP between genders, although both increased with age. During exercise, SBP rose and DBP fell in both genders. SBP variation was greater in men, particularly in those over 14 years of age.

Conclusion: Analysis of results showed that during physical exercise, SBP had a direct relationship with the individual's age, weight, height and body mass index, whereas DBP bore a relationship to age only.

Key words: Exercise stress test, adolescents, arterial blood pressure.

Introduction

Arterial blood pressure (BP) is the main element used to indirectly assess the heart's inotropic response to physical exertion associated with the level of exercise tolerance.[1] To date, there is no consensus over the normal values of blood pressure variation with physical exertion. Further studies should be conducted to establish patterns for young and old, male and female, white and black individuals.[1] The hyperreactive response of BP to physical exertion in normotensive individuals has a predictive value for the later development of arterial hypertension, with a 2-4 fold increased probability of developing this clinical condition[1-3].

The exercise stress test (EST) in children and adolescents has several indications, among which the assessment of the levels of functional capacity to participate in vocational, leisure and sport activities, as well as to observe the arterial pressure response to exertion[4,5].

Several studies have shown hemodynamic responses and gas exchanges in adults who do the exercise stress test with a ramp protocol[6-10]. Most studies with children and adolescents are performed on a treadmill according to the Bruce protocol[5,11,12], but many do not report data on the arterial blood pressure response.

This study was undertaken to: 1) describe arterial blood pressure response in adolescents undergoing the treadmill exercise test; 2) describe systolic and diastolic arterial pressure values at maximal physical exertion and at six minutes after the exercise; 3) describe systolic and diastolic pressure variations during exertion; 4) determine the role of gender, age, weight, height and body mass index (BMI) on the behavior of arterial pressure during physical exertion.

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Methods

A descriptive case series-type study was carried out with data from the ergometric tests conducted by one single investigator from April 1998 to April 2004. One hundred and thirty-one male and 87 female adolescents with no known cardiac disease were selected. They were 10 to 19 years old (mean age 13.7$\pm$ 2.5 years) and were referred for exercise stress tests to primarily assess functional capacity, arrhythmia or chest pain. Tests from healthy individuals with a HR greater than or equal to 180 bpm who interrupted the test because of fatigue were included. Patients with systemic blood pressure referred for BP evaluation or who were on medications that could interfere with the behavior of arterial pressure (bronchodilator, beta-blockers and sympathomimetic agents) were not included.

Guidelines set by the Brazilian Society of Cardiology were followed as to the temperature and humidity in the laboratory. Body weight and height measurements were obtained using a Filizola anthropometric scale, and participants were classified as to the presence of obesity according to the criteria described by Cole et al[13]. Before placing the electrodes for electrocardiographic monitoring, each placement site was cleaned with an alcohol swab. Before the test, anamneses were obtained and all patients underwent physical examinations, heart rate and arterial blood pressure measurements, as well as a surface electrocardiogram; these procedures were repeated every two minutes during the test. After the stress test, patients were monitored during six minutes or more when necessary. Arterial blood pressure was measured with an aneroid sphygmomanometer that is calibrated twice a year. The tensiometer cuff width measured approximately 2/3 of an arm length and was appropriately fit according to the subject's size.

All participants did the treadmill exercise test using a ramp protocol, with small continuous increments in exercise intensity and speed, and treadmill inclination adjusted according to the patient's age and gender[14]. Korotkoff phase I was used to define systolic BP (SBP) and phase V was used for the diastolic BP (DBP)[15-18]. For the analysis of the results, measurements of BP at rest, at maximal exertion and six minutes after the test were used.

Participants were assigned to 5 groups according to their age: 10 to 11 years; 12 to 13; 14 to 15; 16 to 17, and 18 to 19 years. The comparison among the age groups and genders was made using the variance analysis (ANOVA) and the non-paired Student's *t*-test, respectively. The linear correlation among the variables was also analyzed. When needed, the Mann-Whitney test and the paired Student's *t*-test were used. Error was considered as $\alpha=5\%$ (significance $p\leq 0.05$). Data were processed using Microsoft(R) Excel 8.0, whereas the statistical analysis was performed using Sigmastat 3.0 and SPSS (Statistical Package for Social Science), version 8.0.

The project was presented and approved by the Human Research Ethics Committee of the *Centro de Ciências da Saúde* of the *Universidade Federal de Pernambuco*.

Results

In the study population, 79.8% had a normal BMI according to the criteria described by Cole et al[13].

The duration of exercise was 10:57$\pm$01:35 min. for males and 10:05$\pm$00:35 min. for females ($p<0.001$). No significant difference was found by comparing the age groups of patients of the same gender. The maximal heart rate was similar in both genders (192$\pm$08 bpm). Among male patients, maximum HR values were smaller in the group 10 to 12 years of age ($p = 0.021$). Maximal inclination and velocity and VO_2 max. were greater among boys (16.9$\pm$2.9%, 8.8$\pm$1.1 km/h and 55.7$\pm$7.4 ml/kg/min, respectively) than among girls (15.6$\pm$2.1%, 7.6$\pm$0.8 km/h and 46.7$\pm$5.8 ml/kg/min, respectively), with $p<0.001$. No significant difference was identified in the analysis by age groups.

Arterial pressure behavior - Resting DAP showed no significant difference between genders ($p=0.578$). Resting SAP was greater in males when compared to females ($p\leq 0.001$). A similar resting BP pattern was observed in all periods evaluated during the stress test, that is, with no difference in DBP between genders and a greater SBP values for boys (Tabs. 1 and 2).

Table 1 - Systolic and diastolic arterial pressure (mmHg) at rest (R), maximal effort (Max), and 6 min after exertion (R6) by age bracket in male adolescents evaluated by exercise stress test from April /1998 to April/2004 – Recife/PE

	Systolic blood pressure (SBP)			Diastolic blood pressure (DBP)		
	SBP R	SBP max	SBP R6	DBP R	DBP max	DBP R6
Age Range (years)	mean ± SD	mean ± SD	mean ± SD	mean ± SD	mean ± SD	mean ± SD
10 - 11	106.4 ± 6.6	126.1 ± 14.4	107.9 ± 8.8	65.3 ± 4.8	56.0 ± 10.9	61.9 ± 7.3
12 - 13	110.5 ± 10.9	133.9 ± 21.1	111.1 ± 11.0	67.3 ± 7.0	49.1 ± 17.6	60.8 ± 9.2
14 - 15	117.8 ± 9.4	154.2 ± 19.7	117.0 ± 12.6	72.8 ± 5.5	55.5 ± 17.0	63.0 ± 8.5
16 - 17	122.6 ± 9.7	162.2 ± 21.8	123.4 ± 11.3	74.6 ± 8.0	63.0 ± 16.3	65.4 ± 2.8
18 - 19	127.8 ± 4.4	174.4 ± 11.8	133.3 ± 10.9	78.9 ± 3.3	71.1 ± 10.8	70.6 ± 9.5
Total	114.6 ± 11.3	144.7 ± 24.6	115.5 ± 13.1	70.2 ± 7.5	56.4 ± 16.5	63.4 ± 10.0

Table 2 - Systolic and diastolic arterial pressure (mmHg) at rest (R), maximal effort (Max), and 6 min after exercise (R6) by age bracket of female adolescents evaluated by exercise stress tests from April /1998 to April/2004 – Recife/PE

	Systolic blood pressure (SBP)			Diastolic blood pressure (DBP)		
	SBP R	SBP max	SBP R6	DBP R	DBP max	DBP R6
Age Range (years)	mean ± SD	mean ± SD	mean ± SD	mean ± SD	mean ± SD	mean ± SD
10 - 11	105.3 ± 8.7	120.0 ± 18.5	101.5 ± 6.8	65.0 ± 6.9	47.9 ± 11.2	55.9 ± 7.6
12 - 13	107.1 ± 7.6	125.0 ± 15.4	105.8 ± 7.3	68.7 ± 6.1	57.5 ± 10.5	62.3 ± 6.3
14 - 15	111.4 ± 10.5	136.9 ± 15.4	111.1± 9.0	68.6 ± 6.1	63.3 ± 12.5	65.6 ± 8.4
16 - 17	114.2 ± 10.4	135.8 ± 10.2	108.3 ± 9.1	77.5 ± 5.4	66.3 ± 9.3	65.4 ± 8.7
18 - 19	112.8 ± 11.8	138.9 ± 11.9	112.2 ± 8.3	72.8 ± 9.4	62.8 ± 10.0	67.2 ± 8.7
Total	109.3 ± 9.9	129.6 ± 16.8	107.1 ± 8.7	69.6 ± 7.4	58.5 ± 12.2	62.7 ± 8.4

A positive correlation was observed between the resting systolic and diastolic BP and age, weight, height and BMI (except for systolic BP and BMI in girls).

The relationship between the maximum SBP measured and the independent variables in the analysis shows positive and statistically significant correlations for both genders. The correlation between the maximum DBP measured and age, height, weight and BMI shows a significant association with age in both genders. Among girls, a significant correlation between the maximum DBP and weight and height was also observed.

For all age groups and both genders a rise in SBP and a drop in DBP values were observed during exercise. The SBP variation (ΔSBP) was 20.3±13.9 for females and 30.1±17.3 for males (p≤0.001). The DBP variation (ΔDBP) was negative 11.4±10.1 for females and 13.9±14.2 for males (p=0.324). The greatest variations in SBP were observed in the older aged groups (over 14 years) for both genders, particularly among boys.

A significant and positive association was found in all correlations for the ΔSBP variable and all independent variables analyzed for both genders. The same thing happened for the ΔSBP/MET variable.

Using the analysis of variance (ANOVA) and according to the classification of obesity[13], a difference was observed in maximum SBP, ΔSBP, and SBP in the first minute of recovery (p=0.022, p=0.032, and p=0.010, respectively) among overweight and obese adolescents and those with a normal BMI.

Among boys, the SBP measured in the sixth minute after exercise (115.5±13.1 mmHg) was similar to the resting SBP (114.6±11.3 mmHg). Among girls, the measurement of SBP in the sixth minute after exercise (107.1+8.7 mmHg) was lower than the resting SBP (109.3+9.9 mmHg), with a significant difference (p=0.028). The DBP in the sixth minute after exercise (males 63.4±10.0 mmHg and females 62.7±8.4 mmHg) was smaller than the resting DBP (males 70.2+7.5 mmHg and females 69.6±7.4 mmHg), with a significant difference (p≤0.001) in both genders.

Discussion

The importance of knowing the arterial pressure response to exercise in children and adolescents has been the focus of several studies in many countries, and these have confirmed that there are differences when diverse populations are compared[5,12,19-23]. Some of these differences can be attributed also to the different methodologies and test protocols used. In most studies, children and adolescents were evaluated by means of multistage protocols, particularly the treadmill test developed by Bruce.

In this series, no difference was observed in resting DBP between the two genders. Increasingly greater values were observed with age, mainly from 16 years on, in both genders. Resting SBP values were significantly greater among males (p≤0.001). As for females, no difference was found among the age groups. Mafulli et al[12] and Ahmad et al[22] reported similar findings on the behavior of SBP at rest. However, other authors[19,20] did not identify differences between genders.

Resting SBP values described for a North-American population are slightly lower than those in this study[22]. This may be due to the different age groups evaluated in both studies. The DBP values at rest are also different. The use of different criteria to define DBP in both studies may explain this dissimilarity since the North-American population study had defined the Korotkoff phase IV as the criterion for DBP determination.

As to the behavior of BP during physical exertion, SBP levels for children and adolescents at maximal exhaustion are expected not to exceed 200 mmHg. A significant increase in DBP during physical exertion is uncommon, and usually the values at rest either drop or remain unchanged[4].

Studies conducted with children and adolescents using the Bruce protocol have consistently reported a SAP behavior similar to that observed in adults, i.e., a rise in tension levels with exercise[5,12,19,20,22]. However, these same studies are controversial as to DBP behavior. Some have shown a drop in DBP, whereas others have reported the maintenance of the levels observed at rest, and seldom, a rise in diastolic tension levels.

The findings in this study were similar to those reported in medical literature, i.e., a rise in SBP and a drop in DBP levels during physical exercise for both genders in all age groups. As expected, the magnitude of the SBP increase was greater among male patients since after puberty men have greater maximal systolic volumes than women. Increases in age, height, and weight resulted in increased SBP levels in both genders, more clearly among males.

Similarly to the findings reported by Ahmad et al[22], the greatest variations in SBP were observed in the age groups over 14 years for both genders. However, variations of SBP, as well as those of the maximal exertion SBP reported by these authors, are greater than those identified in this series.

Studies conducted with children and adolescents using the Bruce protocol [5,12,19,22] showed higher SBP levels than those observed in this study, even for those who used a similar BP measurement method. The greater BP levels were reported in studies that used an automatic measurement method[19,22]. Although maximal exertion BP could not be measured in many patients of this series, even when only adolescents with clearly auscultated BP were considered, the difference relative to the studies on the Bruce protocol remains. This may reflect a better adaptation of the body to the ramp protocol in which the workload is increased slowly and frequently, with no abrupt changes, so that the arterial blood pressure also rises more gradually.

The exertional DBP variation was also greater among males, but it shows a drop with exercise in both genders and for all age groups evaluated. A significant association was observed only for age related to the maximum DBP measured, with levels in subjects over 14 years of age among females and over 16 years of age among males. This DBP behavior during exercise is different from that of other studies[12,19,20,23] that reported unchanged DBP levels during exercise or a tendency to decrease. In the study conducted with the North-American population[22], contrary to the findings in medical literature and in this series, a rise in DBP with exercise was reported.

In one study undertaken in Venezuela[24] with children and adolescents from 8 to 17 years of age using the Cumming protocol, a SBP variation of up to 30 mmHg was found to be a normal response to exercise. In this series, a similar variation in SBP was observed, though with a significant standard deviation (ΔSBP: 30.1+17.3 mmHg). This may be due to the different age groups evaluated in the studies. The assessment of adolescents at an age group closer to the transition to adulthood, when the ΔSBP is expected to be over 35 mmHg, may have also played a role.

In this study, overweight or obese adolescents had higher arterial blood pressures at maximal exertion and ΔSAPs when compared to those with normal BMIs ($p=0.002$ and $p=0.0032$ respectively). This shows the influence of hyperinsulinemia, likely to affect overweight and obese patients, on the cardiovascular system and on the response to exercise.

As to the BP behavior after the exercise, Arenas et al[23] have shown the return of BP to baseline levels after approximately nine minutes of recovery. Ahmad et al[22] observed a similar pattern, with the BP reaching levels similar to those at rest ten minutes after the exercise. In this series, a gradual decrease in systolic and diastolic components of the arterial pressure was observed, reaching levels similar to those at rest in the sixth minute.

The BP findings described may serve as a comparison to other studies that use the ramp protocol to evaluate adolescents (Tabs. 1 and 2). This series, that described the behavior of arterial pressure on exertion among 218 otherwise normal adolescents, is part of a more comprehensive project involving a second group with suspected arterial hypertension and a third study underway which is evaluating overweight or obese adolescents and a normal-weight control group.

The results obtained in this series allow us to conclude that the behavior of arterial blood pressure under physical exertion in healthy adolescents shows a rise in the systolic component and a drop in the diastolic component in both genders. Arterial blood pressure during physical exertion has a direct relationship with age, weight, height, and BMI in both genders, whereas the diastolic arterial pressure has a direct relationship with the individual's age in both genders.

Potential Conflict of Interest

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

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