








ORIGINAL ARTICLE

Blood pressure responses to the Cold Pressor Test according to body mass index and waist-to-height ratio in adolescents

Respostas de pressão arterial ao Cold Pressor Test de acordo com o índice de massa corporal e relação cintura-estatura de adolescentes

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KEYWORDS

Adolescent
Arterial pressure
Overweight

ABSTRACT

Objectives: to analyze the blood pressure (BP) values and responses to the Cold Pressor Test (CPT) according to the body mass index (BMI) and the waist-to-height ratio (WHtR).

Methods: 166 adolescents of both sexes participated in the study. Participants underwent measurements of body mass, height and waist circumference. BMI and WHtR were calculated. BP was measured before (pre-test), during (test) and after CPT (recovery). The groups were compared using a mixed ANOVA with Bonferroni post hoc, and Odds Ratio calculation. The level of significance was $p < 0.05$.

Results: prevalences of 16.9% of high BMI, 19.9% of increased WHtR and 8.4% of pretest BP were found above the recommended. Participants with high BMI had increased systolic BP compared to their normal peers (113.0 ± 11.4 vs. 121.7 ± 11.6 mmHg; $p = 0.003$). Adolescents with elevated WHtR had higher pre-test and recovery systolic BP (pre-test: 113.2 ± 11.4 vs. 119.6 ± 12.7 mmHg; $p = 0.021$; recovery: 111.9 ± 14.1 vs. 117.4 ± 14.0 mmHg; $p = 0.044$). Finally, individuals with BMI and WHtR above the recommended had 2.1 (95% CI 0.62 - 7.36) and 2.5 (95% CI 0.77 - 7.91) times, respectively, more likely to have high pre-test BP values.

Conclusion: adolescents with increased BMI and WHtR have higher BP values compared to their normal peers.

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PALAVRAS-CHAVE

Adolescente
Pressão Arterial
Sobrepeso

RESUMO

Objetivos: analisar os valores e as respostas de pressão arterial (PA) ao *Cold Pressor Test* (CPT) de acordo com o índice de massa corporal (IMC) e a relação cintura-estatura (RCE). **Métodos:** 166 adolescentes de ambos os sexos participaram no estudo. Os participantes foram submetidos a medidas de massa corporal, estatura e circunferência da cintura. IMC e RCE foram calculados. A PA foi medida antes (pré-teste), durante (teste) e após o CPT (recuperação). Os grupos foram comparados por meio de uma ANOVA mista com *post hoc* de Bonferroni, e cálculo do *Odds Ratio*. O nível de significância foi $p < 0,05$.

Resultados: foram encontradas prevalências de 16,9% de IMC elevado, 19,9% de RCE aumentada e 8,4% de PA pré-teste acima do recomendado. Participantes com IMC elevado apresentaram PA sistólica aumentada quando comparada aos seus pares normais ($113,0 \pm 11,4$ vs. $121,7 \pm 11,6$ mmHg; $p = 0,003$). Adolescentes com RCE elevada obtiveram maior PA sistólica pré-teste e na recuperação (pré-teste: $113,2 \pm 11,4$ vs. $119,6 \pm 12,7$ mmHg; $p = 0,021$; recuperação: $111,9 \pm 14,1$ vs. $117,4 \pm 14,0$ mmHg; $p = 0,044$). Por fim, indivíduos com IMC e RCE acima do recomendado apresentaram 2,1 (IC 95% 0.62 - 7.36) e 2,5 (IC 95% 0.77 - 7.91) vezes, respectivamente, mais chances de apresentarem valores elevados de PA pré-teste.

Conclusão: adolescentes com IMC e RCE aumentados apresentam valores maiores de PA em comparação aos seus pares normais.

INTRODUCTION

Several factors can cause obesity. Therefore, its treatment is challenging and expensive¹⁻⁴. Moreover, obesity is one of the most important and prevalent risk factors for the health of children and adolescents around the globe. In general, excessive weight is associated with a combination of low physical activity levels and high sedentary behavior⁵.

According to studies, physically active adolescents are more likely to become healthy adults. Chronic diseases such as coronary heart disease, hypertension and type 2 diabetes are uncommon in youth. However, as the prevalence of obesity increases and physical activity levels decrease, these diseases have become more common in this population⁶⁻⁷.

According to Mazzocante et al.¹, excessive weight has also been associated with cardiovascular diseases. Pozuelo-Carrascosa et al.⁸ reported that increased blood pressure (BP) during childhood is associated with a high risk of hypertension in adulthood. The authors also stated that high body fat percentages in youth increase the risk of coronary heart disease and premature death in adulthood. Lastly, the authors referred that hypertension is a chronic disease with a 3% to 5% estimated prevalence in children.

A straightforward way of verifying blood pressure responses after being exposed to a stress agent is using the Cold Pressor Test (CPT). In this test, the individual immerses one of the body's extremities in a container with cold water (between 4.0 and 5.0 °C) for one minute. Blood pressure is measured before the test (pre-test), at the 60th second of the test (test), and one minute after the test is completed (recovery)⁹⁻¹⁰.

Therefore, it is crucial to analyze and closely follow blood pressure responses of adolescents according to their anthropometric profile to better understand how much body composition affects the blood pressure of individuals in their "teens". Thus, the present study aimed to compare blood pressure values and blood pressure responses during the CPT in

adolescents according to anthropometric indicators.

METHODS*Participants*

This convenience sample consisted of 166 adolescents from both sexes (105 girls) between 14 and 17 years. All students attended a public school in the city of Triunfo, State of Pernambuco, Brazil. To participate in the study, students had to present a free, informed consent form signed by their parents or guardians. Data were collected during the second semester of 2017.

Ethical Approval

The Ethics Committee of the Federal University of Vale do São Francisco (UNIVASF) approved the present study under the protocol number 2.202.850 (CAAE: 67710517.4.0000.5196).

Procedures and Instruments

To assess body weight, a digital scale (Wiso®, Brazil) with a 100 g precision was used. Height was measured using a portable stadiometer (Wiso®, Brazil) with a 0.1 cm precision. During height measurements, the subjects remained standing with their ankles, calves, buttocks, back, and head touching the wall. The head position was consistent with Frankfurt's Plan, and the measurement was performed at the moment of inhaling air.

The subjects' body mass index (BMI) was calculated from the division of body weight (in kilograms) by height (in meters) raised to the second power (kg.m^{-2}). Overweight and obesity were determined according to the BMI z-scores for age proposed by the World Health Organization¹¹. Overweight was considered when the volunteer

presented a z-score between +1.00 and +1.99, while obesity was characterized as z-score equal to or higher than +2.00. In order to perform statistical analysis, overweight and obese individuals were grouped.

Waist circumference was measured with a non-extendible tape (CESCORF®, Brazil) with a precision of 0.1cm. The measurement was made between the last rib and the iliac crest. Waist-to-height ratio (WHtR) was calculated by dividing waist circumference (cm) by height (cm) and values were considered high when equal or above the 75th percentile for sex and age, according to Ramires-Vélez et al.¹².

Blood pressure was measured using a validated automatic oscillometric device (BP A100, Microlife®, China)¹³ in three distinct moments:

1. Pre-test: after 10 min in a seated position
2. Test: during the application of a cardiovascular stress test (at the 60-sec mark of the CPT)
3. Recovery: 1 min after the CPT

All measurements were performed in a seated position in a quiet room with the subjects' left arm at the heart level, as recommended by the Brazilian Cardiology Society¹⁴. Blood pressure pre-test was considered high when SBP or DBP presented values equal or above the 95th percentile for the subjects' age, sex, and height percentile¹⁵.

The cardiovascular stress test was induced in the volunteers using the CPT^{9,10}. The subjects immersed their right hand up to the wrist in a container filled with cold water (4°C to 5°C) for 1 min. The temperature of the water was controlled using an infrared thermometer (Cason® CA380, China). Blood pressure reactivity was assessed at the 60-sec mark of the CPT (test) and the first minute after finishing the test (recovery). Subjects that presented an increase in blood pressure equal or above 25 mmHg or 20 mmHg for SBP or DBP, respectively, were considered hyper-reactive compared to blood pressure pre-test. Lower values were considered as normoreactive¹⁰.

Data Analysis

Data were initially analyzed through descriptive statistics: mean, standard deviation, relative frequency (%) and absolute frequency (n). Afterward, a Kolmogorov-Smirnov's test was performed, which confirmed that data was normal. A mixed ANOVA with Bonferroni's *post hoc* was conducted to compare groups at pre-test, during the test and after CPT (recovery). Lastly, the odds ratio (OR) was calculated to verify the risks of having high blood pressure values pre-test according to BMI and WHtR classification. The level of significance adopted was $p < 0.05$, and the software used to perform the analysis was IBM SPSS Statistics for Windows, Version 22.0 (Armonk, NY: IBM Corp).

RESULTS

Twenty-eight participants (16.9%) presented excessive weight according to BMI, while 33 (19.9%) had WHtR above recommended. Blood pressure pre-test was increased in 14 individuals (8.4%) and 49 (29.5%)

were hyper-reactive to the CPT. The main characteristics of the sample are shown in Table 1.

Figures 1 and 2 show systolic (SBP) and diastolic (DBP) blood pressure responses throughout CPT according to BMI classifications. Significant differences were found at pre-test, where participants with excessive weight showed higher SBP when compared to their normal peers (113.02 ± 11.40 vs. 121.71 ± 11.61 mmHg; $p = 0.003$). SBP was higher during the test when compared to pre-test values in the normal group (123.49 ± 17.16 vs. 113.02 ± 11.40 mmHg; $p < 0.001$), and during the test when compared to recovery in both groups (normal: 123.49 ± 17.16 vs. 112.20 ± 13.98 mmHg; $p < 0.001$; excessive weight: 127.50 ± 14.34 vs. 116.68 ± 15.06 mmHg; $p < 0.001$). Significant differences were found between DBP values during the test when compared to pre-test in both groups (normal: 79.92 ± 12.34 vs. 65.82 ± 6.75 mmHg; $p < 0.001$; excessive weight: 77.82 ± 14.07 vs. 67.64 ± 6.85 mmHg; $p < 0.001$), and during the test when compared to recovery (normal: 79.92 ± 12.34 vs. 65.80 ± 8.07 mmHg; $p < 0.001$; excessive weight: 77.82 ± 14.07 vs. 66.57 ± 8.82 mmHg; $p < 0.001$), also in both groups.

Table 1 - Main characteristics of the participants (n = 166), Triunfo, PE, Brazil (2017).

Variables	Mean \pm SD
Age (years)	16.10 \pm 0.80
Weight (kg)	59.05 \pm 10.80
Stature (cm)	166.49 \pm 8.02
Body mass index (kg.m ⁻²)	21.24 \pm 3.11
Waist circumference (cm)	71.78 \pm 6.75
Waist to height ratio	0.43 \pm 0.04
Systolic blood pressure (mmHg)	114.49 \pm 11.86
Diastolic blood pressure (mmHg)	66.13 \pm 6.78

SD, standard deviation.

Comparisons between BP responses, according to WHtR, also showed statistically significant differences. High WHtR participants showed increased SBP values compared to normal at pre-test and recovery (pre-test: 113.23 ± 11.35 vs. 119.58 ± 12.67 mmHg; $p = 0.021$; recovery: 111.86 ± 14.10 vs. 117.39 ± 14.03 mmHg; $p = 0.044$) (Figure 3). When comparing moments, significant increases in SBP were found in both groups during the test compared to the other moments. In the normal WHtR group, the mean value during the test was higher than the pre-test (113.23 ± 11.35 mmHg vs. 123.30 ± 16.68 mmHg; $p < 0.001$). Similar results were found in the high WHtR group comparing pre-test and during the test (119.58 ± 12.67 mmHg vs. 127.64 ± 16.84 mmHg; $p = 0.004$). Increased SBP were also observed when comparing SBP during the test with values at recovery (normal WHtR: 123.30 ± 16.68 vs. 111.86 ± 14.10 mmHg; $p < 0.001$; increased WHtR: 127.64 ± 16.84 vs. 117.39 ± 14.03 mmHg; $p < 0.001$).

Based on WHtR classification, DBP did not show significant differences in the CPT when comparing values between groups (normal and increased), in any moment. However, significant differences were found

between moments. Values during the test were significantly higher in both groups when compared to pre-test (normal WHtR: 79.55 ± 12.30 vs. 65.75 ± 6.58 mmHg; $p < 0.001$; increased WHtR: 79.64 ± 14.10 vs.

67.64 ± 7.47 mmHg; $p < 0.001$) and to recovery (normal WHtR: 79.55 ± 12.30 vs. 65.87 ± 7.78 mmHg; $p < 0.001$; increased WHtR: 79.64 ± 14.10 vs. 66.18 ± 9.72 mmHg; $p < 0.001$), as shown in Figure 4.

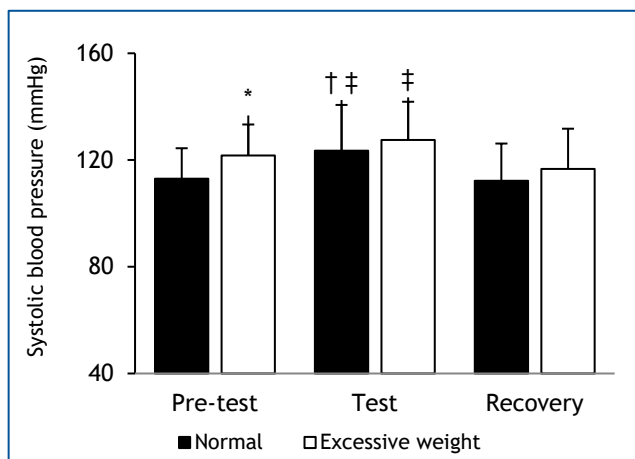


Figure 1 - Systolic blood pressure values throughout the cold pressor test according to body mass index (BMI) classification. * $p < 0.05$ compared to normal BMI. † $p < 0.05$ compared to Pre-test in the same group. ‡ $p < 0.05$ compared to Recovery in the same group.

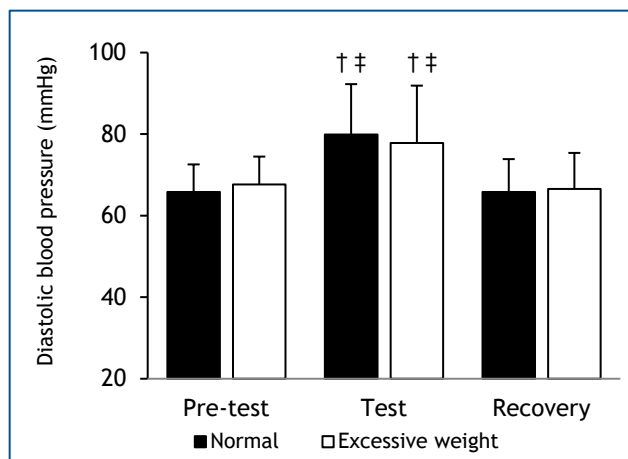


Figure 2 - Diastolic blood pressure values throughout the cold pressor test according to body mass index (BMI) classification. † $p < 0.05$ compared Pre-test in the same group. ‡ $p < 0.05$ compared to Recovery in the same group.

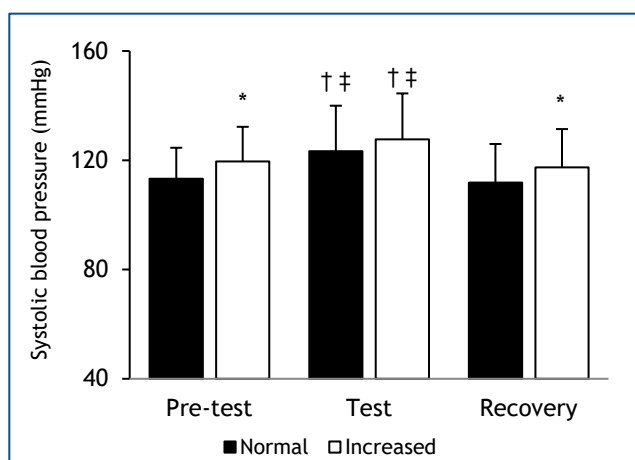


Figure 3 - Systolic blood pressure values throughout the cold pressor test according to waist-to-height ratio (WHtR) classification. * $p < 0.05$ compared Normal. † $p < 0.05$ compared to Pre-test in the same group. ‡ $p < 0.05$ compared to Recovery in the same group.

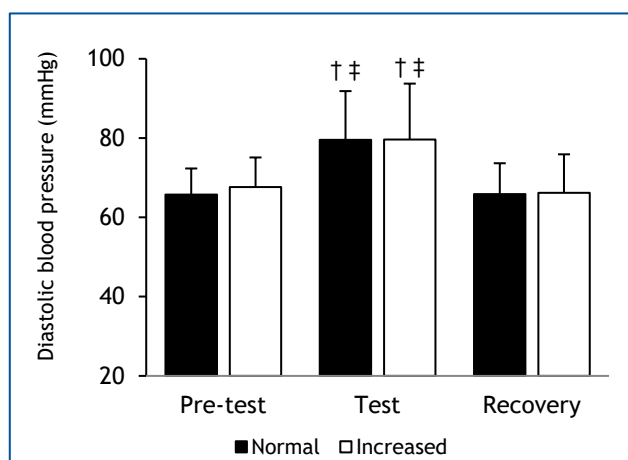


Figure 4 - Diastolic blood pressure values throughout the cold pressor test according to waist-to-height ratio (WHtR) classification. † $p < 0.05$ compared to Pre-test in the same group. ‡ $p < 0.05$ compared to Recovery in the same group.

In addition to BP values, BP responses to the CPT were also analyzed. These were performed by calculating the variation of blood pressure (Δ) between moments (pre-test to test; test to recovery). The results did not show statistically significant differences in BP regarding BMI or WHtR (Table 2). Thus, it is possible to infer that even though BP values seem to be higher in participants with increased BMI and WHtR,

their blood pressure responses are similar to those with normal BMI and WHtR.

Lastly, the OR analysis showed that participants with excessive weight presented 2.133 times more chances of having increased BP pre-test than their normal peers. Regarding WHtR, this value was 2.460 times higher. Even though these results have clinical importance, they did not reach statistical significance (Table 3).

Table 2 - Blood pressure responses to CPT according to body mass index (BMI) and waist-to-height ratio (WHtR) classifications.

Variable	Blood pressure (mmHg)	
BMI	Systolic	
		Δ Pre-test - Test
	Normal	10.46 ± 13.77
	Increased	5.78 ± 12.22
		Δ Test - Recovery
		11.28 ± 15.87
BMI	Diastolic	
		Δ Pre-test - Test
	Normal	14.10 ± 11.25
	Increased	10.17 ± 11.04
		Δ Test - Recovery
		11.25 ± 11.89
WHtR	Systolic	
		Δ Pre-test - Test
	Normal	10.07 ± 13.60
	Increased	8.06 ± 13.71
		Δ Test - Recovery
		11.44 ± 15.66
WHtR	Diastolic	
		Δ Pre-test - Test
	Normal	13.79 ± 11.28
	Increased	12.00 ± 16.33
		Δ Test - Recovery
		13.45 ± 11.19

Table 3 - Odds ratio (OR) of presenting increased resting blood pressure (BP) after the cold pressor test according to body mass index (BMI) and waist-to-height ratio (WHtR).

Groups	Increased pre-test BP		
	OR	95% CI	χ^2 (p-value)
Normal BMI	1	-	1.494 (0.222)
High BMI	2.133	0.618 - 7.363	
Normal WHtR	1	-	2.407 (0.121)
Increased WHtR	2.460	0.765 - 7.908	

DISCUSSION

In the present study, approximately 17% of the participants were overweight or obese, and almost 20% presented an increased WHtR. These findings corroborate with other studies with Brazilian adolescents, such as Carneiro et al.¹⁶, who found 21.2% of excessive weight among adolescents in Goiânia (GO) and Benedet et al.¹⁷, who reported that 19.3% of their sample was overweight or obese.

Moreover, in the present sample, 8.4% of the participants showed increased pre-test BP values. Bloch et al.¹⁸, in a representative study evaluating 73,399 Brazilian adolescents, found a prevalence of hypertension of 9.6%. Souza et al.¹⁹ reported similar results in a sample of Brazilian adolescents.

It is well known that overweight and obese individuals have increased odds of developing

hypertension even at early age, such as during adolescence. According to Bloch et al.¹⁸ the fraction of hypertension attributed to excessive weight is close to 18%. In this scenario, abdominal obesity has been associated with the development of cardiovascular diseases²⁰. Therefore, WHtR has become a more present indicator in studies regarding the associations between excessive weight and hypertension, dyslipidemia and type 2 diabetes²¹.

The present study also showed statistically significant differences between groups throughout the CPT. Regarding BMI, participants with excessive weight showed higher SBP at pre-test when compared to their normal peers. WHtR, on the other hand, showed differences at pre-test and recovery, in which adolescents with increased values showed higher SBP. In a study with a similar design, Moraes et al.²² reported that male adolescents with high BMI for age and body fat percentage presented significantly higher SBP and DBP values compared to their normal peers at pre-test, test and recovery.

Other studies have highlighted the influence of BMI and waist circumference with increased BP values. Rahman et al.²³ reported a higher prevalence of hypertension in children and adolescents with excessive weight. Choy et al.²⁴, studying a sample composed of adolescents, associated higher values of SBP in DBP as waist circumference quartiles increased. According to the authors, the prevalence of hypertension reached almost 40% of the male participants in the highest quartile of waist circumference. Finally, Lu et al.²⁵ stated that being overweight and obese, even during adolescence, increases the risks of developing hypertension.

The comparison between distinct moments of CPT in the same group also resulted in significant

differences, in which BP values during CPT were higher. This is expected since stress is generated due to the hand's immersion in cold water (4°C to 5°C). According to Silverthorn and Michael²⁶, being in contact with the cold water enhances the sympathetic nervous system's activity and promotes blood vessels' constriction, increasing heart rate and heart contractility, and, consequently, BP.

Another analysis performed in the present study encompasses the chances of presenting high resting BP values according to BMI and WHtR classifications. Even though the results were not statistically significant, participants with increased BMI and WHtR presented a 2.133 and 2.460 OR of having high BP values at rest, respectively. Other authors corroborate these findings. Leung et al.²⁷ found a 2.4 OR of being hypertensive in adolescents with high waist circumference values. Basiratnia et al.²⁸ also reported higher chances of presenting elevated BP in overweight and obese adolescences.

These results have clinical relevance since they infer that, even during adolescence, having excessive weight and increased waist circumference predisposes the development of hypertension. Moreover, studies have suggested that overweight and obese individuals during childhood and adolescence often remain with excessive weight during adulthood²⁹. Finally, research has shown that it is easier to develop a healthier and more active lifestyle during early ages³⁰.

Lastly, even though the present study contributes to the literature by associating BP values and BP responses to a stress test (such as the Cold Pressure Test) according to anthropometric parameters, it is worth highlighting some limitations. For instance, BP measurements were only performed pre-test and, even though participants remained seated for 10 min before the measurement, this cannot be considered their resting BP. Also, since the participants of the present study came from one public school and only a specific age range (14 to 17 years) was analyzed, thus, we cannot extrapolate our findings to children and early teenagers. Finally, the present study has a cross-sectional nature, therefore, it is not possible a cause-consequence relation between BP and high BMI and WHtR.

CONCLUSION

Adolescents with increased BMI presented significantly higher SBP at pre-test, while participants with high WHtR showed significantly higher SBP at pre-test and recovery when compared to their normal peers. During the CPT, both SBP and DBP were significantly higher when compared to recovery and rest (except for SBP in adolescents with high BMI). Lastly, no statistically significant differences were found in blood pressure responses between groups.

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