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Important Association between Body Mass Index and Blood Pressure Reactivity in Male Adolescents

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ABSTRACT

Moraes JFVN, Sales MM, Asano RY, Carvalho FO, Moreira SR, Campbell CSG. Important Association between Body Mass Index and Blood Pressure Reactivity in Male Adolescents. **JEPonline** 2014;17 (1):28-39. The purpose of this study was to verify blood pressure (BP) responses to the Cold Pressor Test (CPT) in male adolescents according to their body mass index (BMI) and body fat percentage (BF%). Subjects consisted of 163 male adolescents with a mean age of 16.25 ± 1.32 yrs, body weight of 65.21 ± 12.86 kg, height of 172.71 ± 6.61 cm, and BMI of 21.77 ± 3.65 kg·m^{-2}. Anthropometric assessment and blood pressure measurements were performed at rest, during, and 1 min after the CPT. The results showed that 20.9% of the subjects were overweight or obese, 16.0% had high resting BP and 33.7% were hyper-reactive to the CPT. The subjects with increased BMI presented significantly higher systolic blood pressure (SBP) and diastolic blood pressure (DBP) than their normal weight peers at rest (129.26 ± 13.04 vs. 118.53 ± 11.88 mmHg for SBP, and 73.18 ± 7.63 vs. 68.67 ± 8.73 mmHg for DBP), during (147.56 ± 21.61 vs. 130.54 ± 17.94 mmHg for SBP and 88.88 ± 14.62 vs. 82.26 ± 12.92 mmHg for DBP) and 1 min after CPT (135.70 ± 17.55 vs. 119.58 ± 14.13 mmHg for SBP, and 78.26 ± 10.70 vs. 70.69 ± 9.90 mmHg for DBP), respectively. Subjects with an increase in BMI and BF% presented higher odds of being hyper-reactive to CPT when compared to normal weight adolescents. Therefore, we conclude that overweight and obese adolescents have enhanced blood pressure responses under stress.

Key Words: Obesity, Adolescents, Cold Pressor Test, Blood Pressure Reactivity.

INTRODUCTION

An increase in the prevalence of systemic arterial hypertension (SAH) has been reported in several parts of the world in different populations (45). Aounallah-Skiri et al. (2) stated that in Tunisia the prevalence of pre-hypertension and SAH in children and adolescents is 35.1% and 4.7%, respectively. Oduwole (25) observed that in Nigeria 18.4% and 20.1% of the adolescents presented high systolic and diastolic blood pressure, correspondingly. Flynn and Falkner (13) indicated that in the United States, 15.7% of the adolescents are hypertensive, and Motswagole et al. (23) found that 13.0% of the South African students aged 9 to 15 yrs of age present SAH.

In Brazil, specifically, Reuter et al. (32) reported that 13.5% of the boys aged 7 to 17 yrs present with SAH. Christofaro and colleagues (9) reported the prevalence of 13.4% of hypertension in school children between 10 and 17 yrs of age. Polderman et al. (28) referred to a prevalence of SAH in 16.9% of boys, while Silva et al. (35) diagnosed high blood pressure in 12.4% of the adolescents between 14 and 19 yrs of age. Finally, Moreira et al. (22) stated that 11.7% of the children and adolescents presented high blood pressure (HBP).

Several studies demonstrate a strong association between excessive weight and SAH. Serrano et al. (33) reported that adolescents with increased body mass index (BMI), body fat percentage (BF%), and waist-to-height ratio had significantly higher odds of presenting HBP. Shi et al. (34), for instance, stated that obese adolescents presented a blood pressure 7.6 mmHg higher than their normal weight peers.

While these studies help in understanding the underlying challenges that result in the early onset of high blood pressure, the fact remains that researchers commonly use resting blood pressure measurements. Since most cardiac events usually occur in association with stressful situations (39), it is important to examine blood pressure responses in association with obesity when subjects are experiencing stress.

A simple test to verify blood pressure response to stress is the Cold Pressor Test (CPT). This test consists of immersing one of the body extremities in a container with cold water (between 4ºC and 5ºC) during 1 min. Blood pressure is measured at 30 sec and 60 sec during the test. The highest response found is characterized as peak value. The difference between the peak value and the resting value determines the level of vascular reactivity. Individuals that present an increase of at least 25.0 mmHg or 20.0 mmHg for systolic (SBP) or diastolic (DBP) blood pressure, respectively, are diagnosed as hyper-reactive. Lower values are characterized as normoreactive (14,44).

The purpose of this study was to verify the blood pressure responses to the CPT in male adolescents according to their BMI and BF%. The hypothesis was that excessive weight is also associated with hyper-reactive blood pressure responses as well as hypertension.

METHODS

Subjects

The subjects consisted of 163 male adolescents from 13 to 20 yrs of age who attended three randomly chosen schools of the city of Petrolina, Pernambuco. All male students were invited to participate in the study, but only the students who brought the informed consent term signed by their parents (or by themselves if above 18 yrs of age) were included. The study was approved by the ethics committee of the Catholic University of Brasília (protocol number 195/2010).

Anthropometric Assessment

In order to assess body weight, a digital scale (Wiso®, Santa Catarina, Brazil) with a 100 g precision was used. Height was measured using a portable stadiometer (Wiso®, Santa Catarina, Brazil) with a 0.1 cm precision. During height measurements, the subjects remained at a standing position 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' BMI was calculated from the division of body weight (in kilograms) by height (in meters) raised to the second power ($kg \cdot m^{-2}$). Overweight and obesity was determined according to the BMI z-scores for age proposed by the World Health Organization (46). Overweight was considered when the volunteer presented a z-score between +1.00 and +1.99, while obesity was characterized as having a z-score equal or higher than +2.00. Volunteers with 18+ yrs of age were diagnosed according to their BMI values (overweight: between 25.00 and 29.99 $kg \cdot m^{-2}$; and obesity equal or above 30.00 $kg \cdot m^{-2}$) (43). In order to perform statistical analysis, overweight and obese individuals were grouped.

Triceps skinfold was measured in triplicate using a skinfold caliper (Lange®, California, USA) at the middle point between the acromion and the elbow. Calf skinfold was also measured in triplicate at the point of the calf's larger circumference. Body fat percentage (BF%) was calculated according to Slaughter et al. (36) as follows: BF% = 0.735 (Triceps skinfold + Calf skinfold) + 1.0. Values higher than 20% were considered above normal. All measurements were performed by an experienced evaluator.

Pubertal Stage Assessment

Pubertal stage was assessed using Tanner's stages (20). The subjects looked at illustrative drawings representing Tanner's stages (e.g., from 1 to 5) and indicated which stage they were in.

Blood Pressure Measurements

Blood pressure was measured using a validated automatic oscillometric device (BP A100, Microlife®, China) (42) in three distinct moments: (a) at rest, after 10 min in a seated position; (b) during the application of a cardiovascular stress test (at the 60-sec mark of the CPT); and (c) 1 min after the CPT. All measurements were performed in a seated position in a quiet room with the subjects' left arm at the level of the heart, as recommended by the Brazilian Cardiology Society (38). Resting blood pressure was considered high when SBP and/or DBP presented values equal or above the 95th percentile for the subjects' age, sex, and height percentile (24).

Cardiovascular Stress Test

The cardiovascular stress test was induced in the volunteers using the CPT (14,44). The subjects' immersed their right hand up to the wrist in a container filled with cold water (4ºC to 5ºC) 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 and at the 1 min after finishing the test. Subjects that presented an increase in blood pressure equal or above 25 mmHg or 20 mmHg for SBP and/or DBP, respectively, when compared to blood pressure at rest, were considered hyper-reactive. Lower values were considered as normoreactive (44).

Statistical Analysis

After testing for data normality through skewness and kurtosis values, respecting the interval between -1.00 and +1.00 (26), descriptive statistics (mean ± standard deviation, standard error of the mean, and absolute frequency) were used to describe the results. Student's *t*-test for independent samples was applied in order to verify differences between BMI, BF%, and blood pressure responses at rest, during, and 1 min after the CPT. Odds ratio was calculated to verify the risks of increased BMI and BF% and hyper-reactivity to the CPT. Statistical power was tested *a priori* for all procedures performed (Student's *t*-test and Odds Ratio). For the sample size used in the present study (n = 163), Student's *t*-test presented a Power of 0.95, considering $\alpha = 0.05$ and an effect size of 0.50. Odds Ratio presented a Power of 0.92 considering $\alpha = 0.05$ and $p_0 = 0.1$. The level of significance adopted was set at $P \leq 0.05$; all statistics were performed using SPSS 15.0. The figures were built using Microsoft Excel 2010.

RESULTS

Increased BMI was detected in 20.9% (n = 34) of the subjects. High resting blood pressure was present in 16.0% (n = 26) of the adolescents and 33.7% (n = 55) of the subjects were hyper-reactive to the CPT. Subject characteristics are presented in Table 1. Blood pressure was analyzed according to BMI and BF%. The results show that subjects with increased BMI for their age presented significantly higher SBP and DBP values when compared to subjects with normal BMI for age at rest, during, and 1 min after the CPT (Table 2). Regarding BF%, the subjects with excessive adiposity presented higher SBP at rest and during the CPT. On the other hand, DBP showed significantly higher values only at the 1 min mark after the CPT (Table 3).

Table 1. Characteristics of the Subjects.

Variable	Mean ± SD
Age (yrs)	16.25 ± 1.32
Pubertal stage	4.20 ± 0.64
Body weight (kg)	65.21 ± 12.86
Body height (cm)	172.71 ± 6.61
Body mass index ($kg \cdot m^{-2}$)	21.77 ± 3.65
BMI-for-age z-score	0.12 ± 1.16
Triceps skinfold thickness (mm)	9.08 ± 3.45
Calf skinfold thickness (mm)	10.28 ± 4.19
Body fat (%)	15.26 ± 5.43
Systolic blood pressure (mmHg)	120.77 ± 12.86
Diastolic blood pressure (mmHg)	69.61 ± 8.68

BMI = body mass index, SD = standard deviation

Table 2. Blood Pressure Responses at Rest, During, and 1 min after the Cardiovascular Stress Test (CPT) According to BMI for Age Classification.

Systolic blood pressure			
BMI for Age	**Rest**	**During**	**1 min After**
Normal (n = 129)	118.53 ± 11.88	130.54 ± 17.94	119.58 ± 14.13
High (n = 34)	129.26 ± 13.04*	147.56 ± 21.61*	135.70 ± 17.55*
Diastolic blood pressure			
BMI for Age	**Rest**	**During**	**1 min After**
Normal (n = 129)	68.67 ± 8.73	82.26 ± 12.92	70.69 ± 9.90
High (n = 34)	73.18 ± 7.63*	88.88 ± 14.62*	78.26 ± 10.70*

*P≤0.05 to normal in the same moment.

Table 3. Blood Pressure Responses at Rest, During, and 1 min after the Cardiovascular Stress Test (CPT) According to Body Fat Percentage.

Systolic blood pressure			
Body Fat %	**Rest**	**During**	**1 min After**
Normal (n = 134)	119.74 ± 12.25	132.51 ± 19.30	122.04 ± 15.72
High (n = 28)	126.11 ± 14.57*	142.18 ± 21.48*	128.10 ± 17.66
Diastolic blood pressure			
Body Fat %	**Rest**	**During**	**1 min After**
Normal (n = 134)	69.19 ± 8.61	83.07 ± 13.32	71.49 ± 10.66
High (n = 28)	71.89 ± 8.91	86.96 ± 14.04	76.46 ± 8.57*

*P≤0.05 to normal in the same moment.

Since blood pressure values at rest were significantly different among the subjects with increased BMI and BF%, a net variation analysis was performed to verify if there was a significant increase in blood pressure in the different moments of the CPT. The results indicated that the subjects with high BMI had a significant increase in SBP during the CPT and that both SBP and DBP remained higher 1 min after the test (Figures 1A and 1B). For BF%, net variations between subjects with increased and normal body fat showed no significant differences in the distinct moments of the CPT (Figures 2A and 2B).

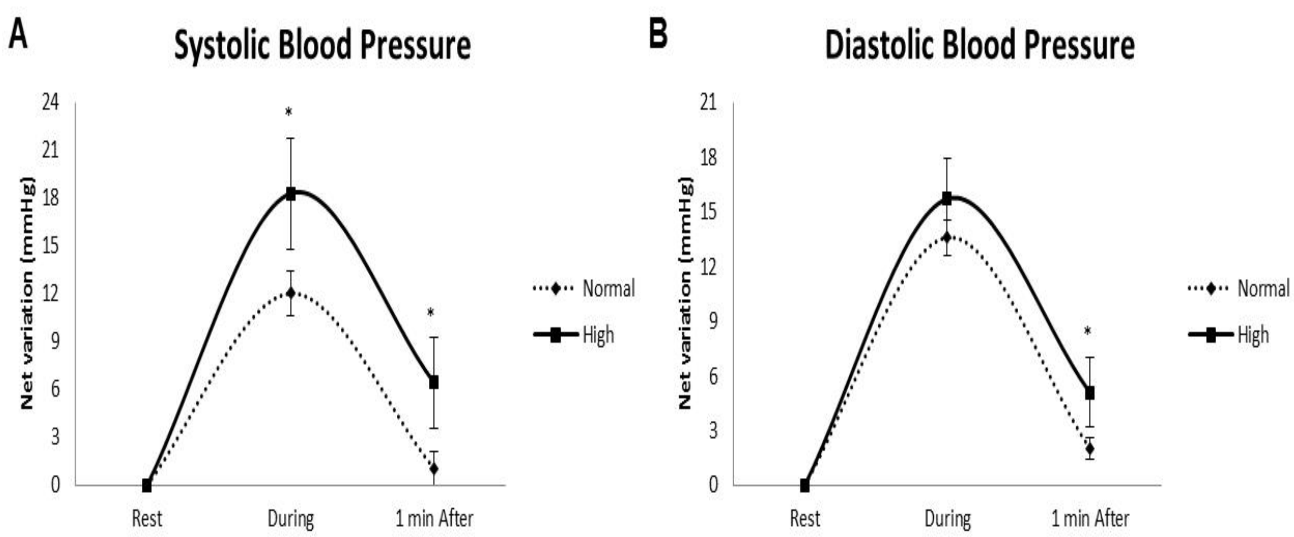

Figure 1. Systolic Blood Pressure (A) and Diastolic Blood Pressure (B) Net Variations at Rest, During, and 1 min after the Cardiovascular Stress Test (CPT) according to the BMI for age. *P<0.05 in the same moment.

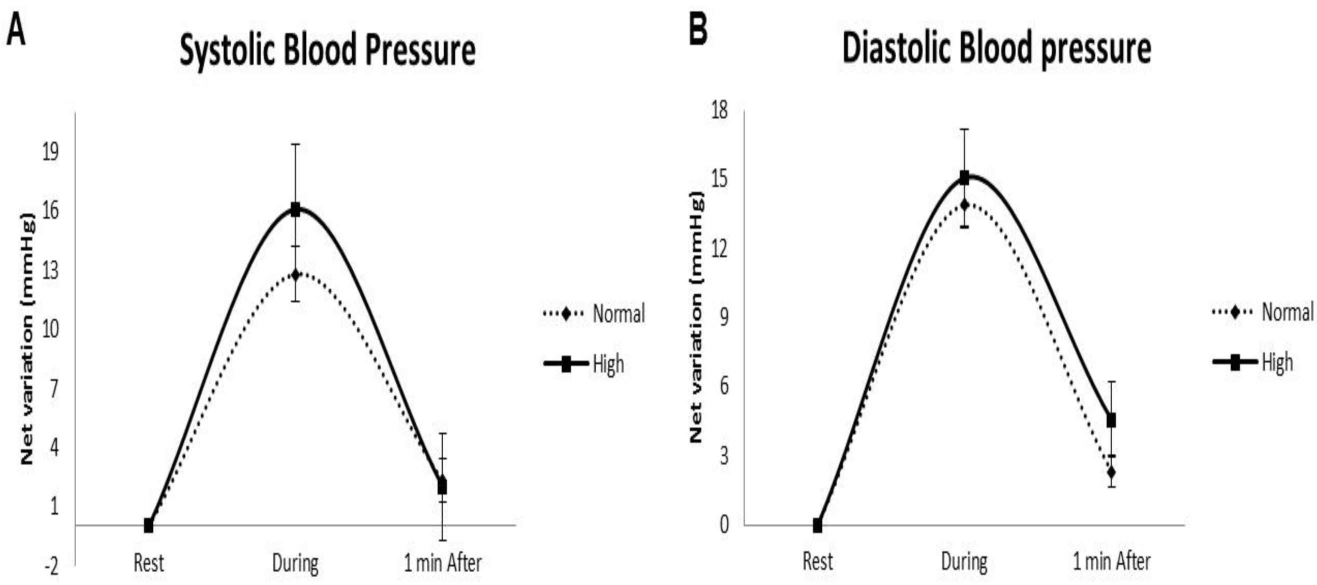

Figure 2. Systolic Blood Pressure (A) and Diastolic Blood Pressure (B) Net Variations at Rest, During, and 1 min after the Cardiovascular Stress Test (CPT) according to the Body Fat Percentage.

Odds ratio analysis revealed that subjects with increased BMI presented 180% more odds of being hyper-reactive to the CPT when compared to their normal BMI peers (X^2 = 7.08; P<0.05). With regards to BF%, subjects with increased body fat showed 59% more odds of being hyper-reactive to the cardiovascular stress test (X^2 = 1.20; P = 0.27), as shown in Table 4.

Table 4. Odds Ratio for Being Hyper-Reactive to the Cardiovascular Stress Test (CPT) according to BMI for Age Z-Score and BF%.

		Hyper-Reactivity to Stress	
n		**Odds Ratio**	**CI (95%)**
129	**Normal BMI**	1	-
34	**High BMI**	2.80*	1.29 – 6.07
134	**Normal BF%**	1	-
28	**High BF%**	1.59	0.69 – 3.65

BMI = body mass index; BF% = body fat percentage. *P<0.05.

DISCUSSION

The main findings of the present study confirmed the initial hypothesis that overweight and obese adolescents would show increased blood pressure responses when compared to their normal weight peers. High BMI and BF% increased 180% and 59%, respectively the odds of being hyper-reactive to the CPT. These findings are in agreement with several studies that associate SAH in children and adolescents with excessive weight.

After evaluating adolescents in Tunisia, Aounallah-Skhiri and colleagues (2) observed a significant positive association between BMI, waist circumference, and blood pressure. They reported that high BMI and waist circumference tripled the odds of developing SAH. Hu et al. (16) indicated that children and adolescents with elevated BMI, waist circumference, and waist-to-height ratio presented 132%, 142%, and 128%, respectively, more odds of being hypertensive. Zhang et al. (47), who also studied adolescents from China, stated that excessive weight was associated with a 40% and a 100% increase in the odds of pre-hypertension and SAH, correspondingly.

In adolescents from Hong Kong, high waist circumference increased the risks of HBP by 2.4 times, while BMI increased the risk of HBP 42.6% (18). Abolfotouh et al. (1) stated that Egyptian adolescents who presented elevated waist circumference and BMI showed significantly increased odds of developing SAH. Other studies have reported similar results in adolescents from Iran (5), Pakistan (29), China (19), and Chile (4). In the present study, even though 20.9% of the subjects were considered overweight or obese, only 2 subjects (1.2%) presented an increased waist circumference in accordance with the percentiles proposed by Fernández et al. (12) and 16 (9.8%) of the subjects had waist-to-height values above 0.50 (27) (data not shown).

The mechanisms that relate SAH to obesity have been associated with insulin resistance, sodium retention, increased sympathetic nervous system activity, activation of the Renin-Angiotensin-Aldosterone System, and changes in vascular function (9,30,31). In addition, possible damages in other organs (heart, arteries, kidneys, retina, and nervous system) should be monitored after diagnosis of SAH (13,40). For example, regarding the heart and arteries, Stabouli et al. (41) and Leite et al. (17) observed an association between blood pressure, BMI, waist circumference and the carotid intima-media thickness in children and adolescents with excessive weight. They and their colleagues indicate that there is a significant positive association between the carotid intima-media's thickness and blood pressure.

Hirschler et al. (15) observed an increase of the left atrial size in obese adolescents when compared to their normal weight peers. According to Ayer et al. (3), the increase in the size of the atrium is associated with co-factors of obesity such as hypertension, diabetes, and sleep apnea. In addition, the authors cited that there is an association between the size of the left atrium and an increased risk of myocardial infarction. Moreover, Bostanci et al. (6) referred to an association between SAH, insulin resistance, and hypertrophy of the left ventricle. Insulin resistance can contribute to SAH through the retention of sodium, activation of the sympathetic nervous system, alteration in the composition and transport of cellular electrons, and stimulation of growth factors (10). Çelik et al. (7) associated excessive weight with arterial stiffness by using pulse wave velocity in children and adolescents aged 10 to 16 yrs. The stiffness of the arteries appears to be attributed to endothelial dysfunctions caused by obesity.

Collectively, these findings partially explain why adolescents with excessive weight respond more intensely to the CPT when compared to normal weight subjects. Therefore, individuals that have other chronic-degenerative diseases can present HBP variations after performing a cardiovascular stress test. Smirnova et al. (37), for instance, stated that patients with type 2 diabetes and glucose intolerance presented higher blood pressure variations and impaired skin temperature responses after performing the CPT. They stated that the impaired responses were associated with endothelial dysfunction.

Moreover, increased blood pressure responses in individuals with excessive body fat can also be explained by the different hormonal and nervous responses presented by obese and normal weight subjects. Epel et al. (11), when comparing cortisol levels among women with high and low waist-to-hip ratio, found that the women with increased waist-to-hip ratio showed higher cortisol values after performing 45 min of tasks involving arithmetic, jigsaw puzzles, and speaking. Monteiro et al. (21) compared the sympathetic autonomic response to the CPT, using heart rate variability in obese and normal weight adolescents and found that excessive weight presented higher sympathetic reactivity.

Limitations

Even though the present study shares important results, it is not without limitations. For instance, we were not able to control other activities performed before the study (physical activity, caffeine or alcohol ingestion, and hours of sleep) that may have interfered in blood pressure behavior. Also, no biochemical markers that may have explained the difference in blood pressure responses between the groups were collected. Therefore, it is not possible to establish a cause-effect relationship among adiposity indicators and blood pressure reactivity.

CONCLUSION

The findings of the present study suggest that the blood pressure responses after performing a cardiovascular stress test (CPT) are enhanced in overweight and obese adolescents when compared to their normal weight peers. In addition, adolescents with excessive weight present higher odds of being hyper-reactive to the CPT.

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REFERENCES

1. Abolfotouh MA, Sallam SA, Mohammed MS, Loutfy AA, Hasab AA. Prevalence of elevated blood pressure and association with obesity in Egyptian school adolescents. ***Internat J Hypertens.*** 2011.

2. Aounallah-Skhiri H, El Ati J, Traissac P, Ben Romdhane H, Eymard-Duvernay S, Delpeuch F, et al. Blood pressure and associated factors in a North African adolescent population: A national cross-sectional study in Tunisia. ***BMC Public Health.*** 2012;12:98.

3. Ayer JG, Sholler GF, Celermajer DS. Left atrial size increases with body mass index in children. ***Int J Cardiol.*** 2010;141:61-67.

4. Balancari R, Díaz C, Martínez-Aguayo A, Aglony M, Zamorano J, Cerda V, et al. Prevalencia de hipertensión arterial y su asociación com la obesidade em edad pediátrica. ***Rev Med Chile.*** 2011;139:872-879.

5. Basiratnia M, Derakhshan D, Adjari S, Saki F. Prevalence of childhood obesity and hypertension in south of Iran. ***Iran J Kidney Dis.*** 2013;7:282-289.

6. Bostanci BK, Civilibal M, Elevli M, Duru NS. Ambulatory blood pressure monitoring and cardiac hypertrophy in children with metabolic syndrome. ***Pediatr Nephrol.*** 2012;27(10):1929-1935.

7. Çelik A, Özçetin M, Yerli Y, Daman IH, Kadi H, Koç F, et al. Increased aortic pulse wave velocity in obese children. ***Arch Turk Soc Cardiol.*** 2011;39(7):557-562.

8. Choy C-S, Chan W-Y, Chen T-L, Shih C-C, Wu L-C, Liao C-C. Waist circumference and risk of elevated blood pressure in children: A cross-sectional study. ***BMC Public Health.*** 2011;11: 613.

9. Christofaro DGD, Ritti-Dias RM, Fernandes RA, Polito MD, Andrade SM, Cardoso JR, et al. Detecção de hipertensão arterial em adolescentes através de marcadores gerais e adiposidade abdominal. ***Arq Bras Cardiol.*** 2011.

10. DeFronzo RA, Ferrannini E. Insulin resistance: a multifaceted syndrome responsible for NIDDM, obesity, hypertension, dyslipidemia, and atherosclerotic cardiovascular disease. ***Diabetes Care.*** 1991;14(3):173-194.

11. Epel ES, McEwen B, Seeman T, Matthews K, Castellazzo G, Brownell KD, et al. Stress and body shape: Stress-induced cortisol secretion is consistently greater among women with central fat. ***Psychosom Med.*** 2000;62:623-632.

12. Fernández JR, Redden DT, Pietrobelli A, Allison DB. Waist circumference percentiles in nationally representative samples of African-American, European-American, and Mexican-American children and adolescents. ***J Pediatr.*** 2004;145:439-444.

13. Flynn JT, Falkner BE. Obesity hypertension in adolescents: epidemiology, evaluation and management. ***J Clin Hypertens.*** 2011;13(5):323-331.

14. Hines EA, Brown, GE. The cold pressor test for measuring the reactibility of the blood pressure: Data concerning 571 normal and hypertensive subjects. ***Am Heart J.*** 1936;11(1):1-9.

15. Hirschler V, Acebo HLP, Fernandez GB, Ferradas S, Oestreicher K. Association between left atrial size and measures of adiposity among normal adolescent boys. ***Pediatr Cardiol.*** 2012; 33:245-251.

16. Hu Y-H, Reilly KH, Liang Y-J, Xi B, Liu J-T, Xu D-J, et al. Increase in body mass index, waist circumference and waist-to-height ratio is associated with high blood pressure in children and adolescents in China. ***J Internat Med Res.*** 2011;39:23-32.

17. Leite A, Santos A, Monteiro M, Gomes L, Veloso M, Costa M. Impact of overweight and obesity in carotid intima-media thickness of Portuguese adolescentes. ***Acta Paediatr.*** 2012; 101:e115-e121.

18. Leung LCK, Sung RYT, So H-K, Wong SN, Lee KW, Lee KP, et al. Prevalence and risk factors for hypertension in Hong Kong Chinese adolescents: Waist circumference predicts hypertension, exercise decreases risk. ***Arch Dis Child.*** 2011;96:804-809.

19. Lu X, Shi P, Luo C-Y, Zhou Y-F, Yu H-T, Guo C-Y, et al. Prevalence of hypertension in overweight and obese children from a large scholl-based population in Shanghai, China. ***BMC Public Health.*** 2013;13:24.

20. Marshall WA, Tanner JM. Variations In the pattern of pubertal changes in boys. ***Arch Dis Child.*** 1970;45:13-23.

21. Monteiro G, Chathoth VM, Kadur K. Cardiac autonomic response during a cold pressor test in normal and overweight adults. ***Int J Biomed Adv Res.*** 2012;3(6):514-516.

22. Moreira NF, Muraro AP, Brito FSB, Gonçalves-Silva RMV, Sichieri R, Ferreira MG. Obesidade: principal fator de risco para hipertensão arterial sistêmica em adolescentes brasileiros participantes de um estudo de coorte. ***Arq Bras Endocrinol Metab.*** 2013;57(7)520-526.

23. Motswagole BS, Kruger HS, Faber M, Van Rooyen JM, De Ridder JH. The sensitivity of waist-to-height ratio in identifying children with high blood pressure. ***Cardiovasc J Afr.*** 2011;22(4): 208-211.

24. National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. ***Pediatrics.*** 2004;114(2 Suppl 4th Report): 555-76.

25. Oduwole AA, Ladapo TA, Fajolu IB, Ekure EN, Adeniyi OF. Obesity and elevated blood pressure among adolescents in Lagos, Nigeria: A cross-sectional study. ***BMC Public Health.*** 2012;12:616.

26. Osborne J. Notes on the use of data transformations. ***Practical Assessment, Research & Evaluation.*** 2002;8(6).

27. Pitanga JF, Lessa I. Razão cintura-estatura como discriminador do risco coronariano de adultos. ***Rev Bras Assoc Med.*** 2006;52(3):157-161.

28. Polderman J, Gurgel RQ, Barreto-Filho JAS, Roelofs R, Ramos EO, Munter JS, et al. Blood pressure and BMI in adolescents in Aracaju, Brazil. ***Public Health Nutrition.*** 2011;14(6):1064-1070.

29. Rahman AJ, Qamar FN, Ashraf S, Khowaja ZA, Tariq SB, Naeem H. Prevalence of hypertension in healthy school children in Pakistan and its relationship with body mass index, proteinuria and hematuria. ***Saudi J Kidney Dis Transpl.*** 2013;24(2):408-412.

30. Raj M. Essential hypertension in adolescents and children: Recent advances in causative mechanisms. ***Indian J Endocr Metab.*** 2011;5:367-373.

31. Raj M. Obesity and cardiovascular risk in children and adolescents. ***Indian J Endocr Metab.*** 2012;16:13-19.

32. Reuter EM, Reuter CP, Burgos LT, Reckziegel MB, Nedel FB, Albuquerque IM, et al. Obesidade e hipertensão arterial em escolares de Santa Cruz do Sul – RS, Brasil. ***Rev Assoc Med Bras.*** 2012;58(6):666-672.

33. Serrano MDM, Armesilla MDC, Moreno MMC, Espinosa MGM, López-Ejeda N, Álvarez JRM, et al. Association between adiposity and blood pressure levels between the ages of 6 and 16 years. Analysis in a student population from Madrid, Spain. ***Rev Esp Cardiol.*** 2013;66(2):110-115.

34. Shi Y, Groh M, Morrison H. Increasing blood pressure and its associated factors in Canadian children and adolescents from Canadian Health Measures Survey. ***BMC Public Health.*** 2012; 12:388.

35. Silva DAS, Lima LRA, Dellagrana RA, Bacil EDA, Rech CR. Pressão arterial elevada em adolescentes: Prevalência e fatores associados. ***Ciência & Saúde Coletiva.*** 2013;18(11): 3391-3400.

36. Slaughter MH, Lohman TG, Boileau RA, Horswill CA, Stillman RJ, Van Loan, MD, et al. Skinfold equations for estimation of body fatness in children and youth. ***Hum Biol.*** 1988; 60(5):709-723.

37. Smirnova E, Podtaev S, Mizeva I, Loran E. Assessment of endothelial dysfunction in patients with impaired glucose tolerance during a cold pressor test. ***Diab Vasc Dis Res.*** 2013.

38. Sociedade Brasileira de Cardiologia; Sociedade Brasileira de Hipertensão; Sociedade Brasileira de Nefrologia. VI Diretrizes Brasileiras de Hipertensão. ***Arq Bras Cardiol.*** 2010; 95(S1):1-51.

39. Sociedade Brasileira de Diabetes. ***Diretrizes da Sociedade Brasileira de Diabetes: 2013-2014.*** São Paulo: AC Farmaceutica, 2013.

40. Spagnolo A, Guissani M, Ambruzzi AM, Bianchetti M, Maringhini S, Matteucci MC, et al. Focus on prevention, diagnosis and treatment of hypertension in children and adolescents. ***Ital J Pediatr.*** 2013;39:20.

41. Stabouli S, Kotsis V, Karagianni C, Zakopoulos N, Konstantopoulos A. Blood pressure and carotid artery intima-media thickness in children and adolescents: The role of obesity. ***Hellenic J Cardiol.*** 2012;53:41-47.

42. Stergiou GS, Giovas PP, Neofytou MS, Adamopoulos DN. Validation of the Microlife BPA100 Plus device for self-home blood pressure measurement according to the international protocol. ***Blood Pressure Monitoring.*** 2006;11(3):157-116.

43. WHO Consultation on Obesity (1999: geneva, Switzerland). ***Obesity: Preventing and Managing the Global Epidemic: Report of a WHO Consultation.*** World Health Organization***.*** 2000.

44. Wood DL, Sheps SG, Elveback LR, Schirger A. Cold pressor test as a predictor of hypertension. ***Hypertension.*** 1984;6:301-306.

45. World Health Organization (WHO). ***A global Brief on Hypertension.*** Geneva: WHO 2013.

46. World Health Organization (WHO). ***WHO AnthroPlus for Personal Computers Manual: Software for Assessing Growth of the World's Children and Adolescents.*** Geneva: WHO, 2009.

47. Zhang C-X, Shi J-D, Huang H-Y, Feng L-M, Ma J. Nutritional status and its relationship with blood pressure among children and adolescents in South China. ***Eur J Pediatr.*** 2012;171: 1073-1079.

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