**Original article**

# Comparison between waist and mid-upper arm circumferences in influencing systolic blood pressure in adolescence: the SHARP (Sardinian Hypertensive Adolescent Research Programme) study

**Pier Paolo Bassareo[1], Andrea Raffaele Marras[1], Claudio Barbanti[2], Giuseppe Mercuro[1]**

[1]Department of Medical Sciences "M. Aresu", University of Cagliari, Italy

[2]Department of Anesthesiology, Intensive Care and Pediatric Cardiac Surgery, Necker-Enfants Malades Hospital, Assistance Publique-Hôpitaux de Paris, Paris, France

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## Abstract

**Background**: The correlation between high blood pressure (BP) and overweight in children is widely acknowledged, although the role of body fat distribution in this association remains to be fully elucidated. The aim of this study was to investigate the role of abdominal (central) and mid-upper arm (peripheral) adiposity in association with BP.

**Methods**: 839 adolescents of both genders took part in the SHARP (Sardinian Hypertensive Adolescent Research Programme) study. BP, waist circumference (WC), mid-upper arm circumference (MUAC), body mass index (BMI) and heart rate were measured.

**Results**: 89 out of 839 subjects were hypertensive (10.6%: 44 males and 45 females. Isolated systolic hypertension: 4.2%; isolated diastolic hypertension: 4.9%; combined systolic and diastolic hypertension: 1.5%). In univariate analysis, WC and MUAC correlated with systolic ($p < 0.0001$ and $p < 0.0007$, respectively), but not with diastolic BP. In multiple longitudinal regression analysis, WC and MUAC were the strongest independent predictors of systolic BP over time. Furthermore, a significant increase of systolic BP was observed throughout all age-adjusted quintiles of WC ($p < 0.001$), while a similar increase was revealed only for the first four quintiles of MUAC ($p < 0.001$). Higher quintiles of central adiposity were associated

with a higher prevalence of elevated systolic BP (p < 0.001), while no similar relationship was detected for MUAC.

**Conclusions**: in adolescence, central and peripheral distribution of body fat is associated with normal systolic BP, irrespective of BMI, with WC alone being correlated to hypertension.

## Keywords

Blood pressure, hypertension, body fat, pediatrics.

## Corresponding author

Pier Paolo Bassareo MD, Department of Medical Sciences "M. Aresu", University of Cagliari, Policlinico Universitario, S.S. 554, bivio di Sestu – 09042 Monserrato (Cagliari), Italy; tel.: +390706754953, fax: +390706754953, e-mail: piercard@inwind.it.

## How to cite

## Background

The relationship between blood pressure (BP) and overweight (OW) has been extensively demonstrated in both adults and children, although varying degrees of correlation have been reported in line with the different methods used to define OW [1-5]. The risk of hypertension in children increases across the entire range of body mass index (BMI) values [6]. However, although BMI is widely used in the classification of OW and obesity, it does not account for the wide variation in fat distribution [6]. Moreover increasing evidence maintains that waist circumference (WC) is a greater risk factor for cardiovascular diseases than general obesity at all ages [8, 9]. In adults numerous anthropometric measurements including BMI, WC, waist-to-hip ratio, waist-to-height ratio, subscapular thickness or triceps skin folds were investigated to evaluate relationship with BP [6, 8, 10-13]. A correlation between BP and issues such as birth weight, placental volume or prepubertal height has also been investigated [14-16].

However, in children the role of body fat distribution in the above association remains to be fully elucidated, particularly in view of the paucity of large-scale studies specifically focusing on the association between BP and body fat accumulation [17]. Accordingly, data obtained from a three-year epidemiologic study [18] was assessed to investigate: a) whether BP values in adolescence were associated with anthropometric measures, such as WC and mid-upper arm circumference (MUAC), and b) the characteristics of this relationship.

## Methods

### Study population

A total of 839 children (441 males [52.6%] and 398 females [47.4%], p = ns) from second-grade schools in Sardinia (Italy) were enrolled in the SHARP (Sardinian Hypertensive Adolescent Research Programme) study [18]. Their characteristics are summarized in **Tab. 1**. BP and anthropometric data of all subjects (age range 11 to 14 years) were measured repeatedly throughout the 3 year study period (seven measurements from February 2005 to June 2007). Informed written consent was obtained from parents of all children taking part in the study, with the exception of 57 subjects excluded following failure of their parents to provide consent. The research was conducted in accordance with the Principles of the Declaration of Helsinki.

### Blood pressure measurements

BP of all participating subjects was measured by two trained paediatric cardiologists according to a standardized recording protocol using a mercury column sphygmomanometer (F. Bosch

**Table 1.** Characteristics of the study population (n = 839).

| Characteristics | Mean | SD | Range |
|---|---|---|---|
| Age (years) | 12.9 | 0.1 | 10.1-15.3 |
| SBP (mmHg) | 112.1 | 11.6 | 84-165 |
| DBP (mmHg) | 64.5 | 8.5 | 46-98 |
| Height (cm) | 154.9 | 8.8 | 122-172 |
| Weight (kg) | 47.1 | 11.7 | 23.2-95.1 |
| BMI (kg/m$^2$) | 19.4 | 3.8 | 12.6-34.3 |
| HR (beats/min) | 86.5 | 14.7 | 50-145 |
| WC (cm) | 74.1 | 8.1 | 54-121 |
| MUAC (cm) | 23.0 | 2.8 | 17.6-33.7 |

SBP: systolic blood pressure; DBP: diastolic blood pressure; BMI: body mass index; HR: heart rate; WC: waist circumference; MUAC: mid-upper arm circumference.
Note: the average of the values obtained from the seven measurements performed during the three year study has been used.

Medizintechnik, GmbH & Co. KG, Bisingen, Germany) equipped with a cuff suited to upper arm circumference [19]. Physicians' ability in measuring blood pressure was previously tested by comparing the blood pressure values they have registered with those registered by a validated automated oscillatometric device (Dinamap, GE Medical System Information Technologies, Inc., Milwakee, Wiscounsin, USA) [20]. Subjects rested quietly for at least 10 minutes with their right arm, not constricted by tight clothing, supported at heart level. A paediatric cuff was used for those with circumferences equal to or smaller than 22 centimetres, and an adult cuff for those with circumference exceeding 22 centimetres. In this way, we ensured that the cuff covered two-thirds of the length of the upper arm. The physicians took care to deflate the cuff slowly, at a rate of 2 millimetres of mercury per second (this was obtained because a device able to regulate cuff deflation was applied to the sphygmomanometer). Systolic and diastolic BP were defined on the basis of phase-1 and phase-5 Korotkoff sounds, respectively. At least three consecutive measurements for both systolic and diastolic pressures were taken for each child, and their mean used for analysis. Italian paediatric BP standards developed following recommendations made by the American Task Force on High blood pressure in Children and Adolescents were used, because using not specific references the prevalence of hypertension is dramatically overestimated [18, 21, 22]. Children were defined as hypertensive when systolic and/or diastolic pressures were above 95th percentile at initial measurement, and remained elevated in subsequent screenings. Heart rate was measured at wrist.

*Anthropometric measurements*

All growing pubescent children were weighed, and WC and MUAC measured, in their underclothes; shoes were removed for height measurement. Weight was measured in kilograms using electronic scales (model 770; Seca, Germany). WC and MUAC were measured in centimetres using a flexible, non-extensible fibreglass measuring tape. Specifically, WC was measured midway between the bottom of the ribs and top of the iliac crest by a single examiner at the end of expiration, as recommended [23]. During measurements, subject were in a standing position with abdomen relaxed, arms at their sides, and feet together. WC has

also been recently proposed as a tool to estimate overweight [24]. MUAC was measured midway between the acromion and olecranon, after marking the acromion with the arm flexed at a 90° angle, with the right arm hanging freely a few centimetres from the side of the body. Height was measured using a standing stadiometer (Holtain, Ltd). BMI was calculated as $kg/m^2$. Maxima uncertainty of up to 100 g was envisaged for weighing, up to 5 mm in height measurements, and up to 1 mm for WC and MUAC.

At least three consecutive measurements for all anthropometric variables were taken for each child, and their mean used for analysis.

*Statistical analysis*

In the statistics, both cross sectional and longitudinal analyses were performed. Specifically, all anthropometric variables were investigated by means of univariate analysis using Spearman's rank correlation test (mean overall values vs mean values obtained at various times throughout the three-year survey) to assess correlation with systolic and diastolic BP. Pearson linear correlation and partial correlation analyses were also used. Three-year longitudinal regression equations were calculated to further adjust for confounders using BP as dependent variable. Using data from all time points on all variables and taking into account the correlation between measurements obtained from the same person, the latter analysis provides for use of all available data, thereby increasing statistical power, and assessing the independent effect of time [25]. To analyze the effect of WC and MUAC on BP, the population sample was divided into quintiles of WC and MUAC. The hypothesised presence of a linear trend in mean values of variables considered was tested across the above-stated quintiles. Results were expressed as means ± standard deviation. The prevalence of high BP across quintiles of both WC and MUAC was tested by chi-squared analysis for linear trend.

Values of p less than 0.05 were set as the minimum level of statistical significance throughout the paper. All statistical analyses were performed using SPSS for Windows version 20.0 (SPSS Inc., Chicago, Il, USA).

**Results**

Eighty-nine participants (44 males, 45 females, p = ns) have been found with systolic and/or diastolic

BP persistently above the 95th percentile, in line with Italian BP paediatric references [18].

Mean systolic BP (50th percentile) was 4 mmHg higher in males than in females (114 mmHg vs 110 mmHg; p < 0.03). No significant difference was found in mean diastolic BP (50th percentile) between males and females (64 mmHg vs 65 mmHg; p = ns).

During the three-year follow up of the SHARP study, 114 young patients persistently featured a WC above the cut-off points for OW (i.e. WC above the 75th percentile specific for their age and sex, proposed by Fernández et al. for all ethnic groups) [26]. The 75th percentile was chosen for WC since the results for all ages studied were below those established for adults (102 cm for men and 88 cm for women). Mean WC was 1.4 cm higher in males than in females (75.9 cm vs 74.5 cm; p = ns).

MUAC was recently proposed as a method for obesity screening, although to date no discernible MUAC cut-off point for OW has been established [27]. Mean MUAC did not significantly differ between males and females (23.2 cm vs 22.6 cm; p = ns).

In univariate analysis systolic BP featured a positive, significant association with BMI, heart rate (HR) and both WC and MUAC (**Tab. 2**). Analyzed according to gender (Pearson linear correlation), the relationship between systolic BP and WC was a little more significant in boys (p < 0.00015) than in girls (p < 0.0005). On the contrary, the relationship between systolic BP and MUAC was a little more significant in girls (p < 0.0004) than in boys (p < 0.001).

The simple correlation coefficient of BMI and WC with systolic BP was slightly higher than that of MUAC with systolic BP. Partial correlation analysis however, revealed that the relationship between WC and systolic BP was unaffected by adjustment for BMI (partial correlation analysis: systolic BP, r = 0.956, p < 0.0008). Indeed, correlation between BMI and systolic BP was no longer significant when controlling for WC (partial correlation analysis: systolic BP, r = 0.166, p = ns).

Partial correlation analysis revealed how the relationship between MUAC and systolic BP was likewise unaffected by adjustment for BMI (partial correlation analysis: systolic BP, r = 0.953, p < 0.0009). On the contrary, correlation between BMI and systolic BP was no longer significant when controlling for MUAC, (partial correlation analysis: systolic BP, r = 0.577, p = ns).

As high collinearity was apparent at univariate analysis, and 3-year longitudinal regression models were computed to assess the relative influence of anthropometric variables on systolic BP. Based on the results of univariate analysis, BMI, WC, MUAC, age, and HR were chosen as independent variables with inclusion of systolic BP as dependent variable. As shown in **Tab. 3** (model 1), WC and MUAC were associated with systolic BP, whereas no additional independent contribution was found for either BMI or age, neither of which met the tolerance criterion for inclusion in the equation. Finally, the inclusion of HR in multiple regression analysis did not modify the results, WC and MUAC being the only significant independent predictors of systolic BP (**Tab. 3**, model 2). As observed previously, once again neither BMI nor HR met tolerance criterion for inclusion in the equation.

Similarly, the relationship between systolic BP and WC was a little more significant in boys (p < 0.0001) than in girls (p < 0.0019) also in longitudinal regression analysis, while an inverse correlation was revealed for MUAC (males: p < 0.0016; females: p < 0.0004).

**Table 2.** Univariate correlations between blood pressure, anthropometric variables, and age (Spearman's rank correlation test).

| Variable | Age | SBP | DBP | HR | BMI | WC | MUAC |
|---|---|---|---|---|---|---|---|
| Age | | 0.501 ( p = ns) | 0.405 ( p = ns) | 0.300 ( p = ns) | 0.995 ( p = 0.0001) | 0.895 ( p = 0.0065) | 0.860 ( p = 0.0130) |
| SBP | | | 0.347 ( p = ns) | 0.816 ( p = 0.0252) | 0.975 ( p = 0.0002) | 0.986 ( p = 0.0001) | 0.958 ( p = 0.0007) |
| DBP | | | | 0.895 ( p = 0.0065) | 0.405 ( p = ns) | 0.650 ( p = ns) | 0.685 ( p = ns) |
| HR | | | | | 0.300 ( p = ns) | 0.405 ( p = ns) | 0.842 ( p = 0.0175) |
| BMI | | | | | | 0.833 ( p = 0.02) | 0.886 ( p = 0.0079) |
| WC | | | | | | | 0.972 ( p = 0.0002) |
| MUAC | | | | | | | |

SBP: systolic blood pressure; DBP: diastolic blood pressure; BMI: body mass index; HR: heart rate; WC: waist circumference; MUAC: mid-upper arm circumference.
Note: the average of the values obtained from the seven measurements performed during the three year study has been used (cross sectional analysis).

To further analyze the relative influence of WC and MUAC on systolic BP, the entire population was classified by quintiles of WC and MUAC. The non-significant age difference across quintiles was accounted for by entering age as covariate. A graded and statistically significant increase of systolic BP was observed across all quintiles of WC, while the increase in systolic BP was of comparably strong statistical significance only across the first four quintiles of MUAC (**Tab. 4** and **Tab. 5**, respectively). In particular, placement in the highest WC quintile and in the fourth MUAC quintile was associated with higher values of systolic BP. A statistically significant increase in BMI values was also observed in association with the increase in WC and MUAC. As higher values of systolic BP

**Table 3.** Stepwise multivariate regression analyses with systolic blood pressure as dependent variable.

| Variable | B | 95% CI of B | t | p value | Change in $R^2$ |
|---|---|---|---|---|---|
| Model 1. Dependent variable: SBP (mmHg); independent variables: WC (cm), MUAC (cm), BMI (kg/m²), age (years) | | | | | |
| WC | 0.587 | 0.399-0.775 | 6.19 | 0.0001 | 0.085 |
| MUAC | 0.351 | 0.208-0.494 | 5.28 | 0.0001 | 0.042 |
| Model 2. Dependent variable: SBP (mmHg); independent variables: WC (cm), MUAC (cm), BMI (kg/m²), HR (beats/min) | | | | | |
| WC | 0.638 | 0.381-0.895 | 6.28 | 0.0001 | 0.080 |
| MUAC | 0.336 | 0.177-0.495 | 3.46 | 0.0006 | 0.037 |

SBP: systolic blood pressure; WC: waist circumference; MUAC: mid-upper arm circumference; BMI: body mass index; HR: heart rate; CI: confidence interval
Note: the results were calculated over time (longitudinal analysis).

**Table 4.** Analysis of covariance: age-adjusted blood pressure and other variables by quintiles of waist circumference.

| Waist circumference, in cm: mean (range) | | | | | | |
|---|---|---|---|---|---|---|
| Quintile | I | II | III | IV | V | F (p for trend) |
| | 65.6 (54-68.2) | 71.2 (68.3-74.4) | 76.4 (74,5-80,6) | 86.4 (80.7-92.8) | 104.5 (92.9-121) | |
| Age (years) | 13.5 (13.4-13.6) | 13.5 (12.8-14.2) | 13.1 (14.3-11.9) | 13.8 (13.7-13.9) | 14.4 (14.6-14.2) | |
| SBP (mmHg) | 112.5 (124.9-100.1) | 110.2 (119.2-101.2) | 117.7 (128-107.4) | 125.9 (138.3-113.5) | 126.5 (139.9-13.1) | 8.4 (< 0.001) |
| DBP (mmHg) | 65.1 (70.9-59.3) | 63.7 (74.3-53.1) | 66.0 (73.7-58.3) | 64.6 (75.5-53.7) | 65.0 (72.1-57.9) | 1.2 (ns) |
| HR (beats/min) | 74.7 ( 64.7-84.7) | 72.7 (86.4-59.0) | 84.0 (92.5-75.5) | 93.0 (95.8-90.2 ) | 95.3 (97.0-93.6) | 3.3 (< 0.02) |
| BMI (kg/m²) | 16.5 (17.8-15.2) | 18.1 (19.3-16.9) | 19.9 (21.7-18.1) | 23.7 (25.0-22.4) | 30.4 (30.9-29.9) | 10.3 (< 0.001) |
| MUAC (cm) | 20.8 (22.2-19.4) | 22.2 (23.6-20.8) | 24.0 (25.7-22.3) | 27.4 (29.9-24.9) | 29.0 (30.1-27.9) | 9.1 (< 0.001) |

Age adjusted at 13.66 years. SBP: systolic blood pressure; DBP: diastolic blood pressure; HR: heart rate; BMI: body mass index; MUAC: mid-upper arm circumference. Values are mean ± standard deviation.
Note: the average of the values obtained from the seven measurements performed during the three year study has been used (cross sectional analysis).

**Table 5.** Analysis of covariance: age-adjusted blood pressure and other variables by quintiles of mid-upper arm circumference.

| Mid-upper arm circumference, in cm: mean (range) | | | | | | |
|---|---|---|---|---|---|---|
| Quintile | I | II | III | IV | V | F (p for trend) |
| | 19.4 (17.6-20.2) | 22.1 (20.3-23.6 ) | 25.0 (23.7-26.6) | 28.1 (26.7-29.8) | 32.5 (29.9-33.7) | |
| Age (years) | 13.1 (13.2-13.0) | 13.4 (13.5-13.3) | 13.4 (13.9-12.9) | 13.2 (13.8-12.6) | 14.5 (14.8-14.2) | |
| SBP (mmHg) | 107.7 (120.8-94.6) | 113.4 (121.7-105.1) | 119.7 (131.9-107.5) | 123.9 (136.0-111.8) | 116.2 (118.7-113.7) | 7.2 (< 0.01)* |
| DBP (mmHg) | 66.5 (72.4-60.6) | 69.8 (79.9-59.7) | 67.7 (75.3-60.1) | 65.2 (73.4-57.0) | 68.0 (77.5-58.5) | 1.3 (ns) |
| HR (beats/min) | 80.5 (92.8-68.2) | 78.5 (91.3-65.7) | 81.7 (96.6-66.8) | 92.7 (107.3-78.1) | 85.3 (88.4-82.2) | 2.9 (< 0.04) |
| BMI (kg/m²) | 15.5 (16.4-14.6) | 18.4 (19.6-17.2) | 22.0 (24.1-19.9) | 26.2 (29.1-23.3) | 26.1 (26.8-25.4) | 10.7 (< 0.001) |
| WC (cm) | 66.5 (70.1-62.9) | 71.6 (75.7-67.5) | 80.1 (87.2-73.0) | 90.7 (101.6-79.8) | 88.0 (92.2-83.8) | 8.8 (< 0.001) |

Age adjusted at 13.52 years. SBP: systolic blood pressure; DBP: diastolic blood pressure; HR: heart rate; BMI: body mass index; WC: waist circumference.
Values are mean ± standard deviation.
Note: the average of the values obtained from the seven measurements performed during the three year study has been used (cross sectional analysis).
* p < 0.001 across the first four quintiles.

were associated with higher WC values, analysis of systolic BP across quintiles of WC was repeated using BMI as a covariate. However, the latter did not affect analysis, as the effect of the covariate was not statistically significant.

Specifically, by pooling data across ages, an increase of 1 cm in WC was associated with a mean rise in systolic BP of 2.19 mmHg in males and 0.86 mmHg in females, respectively. In addition, a 1 cm MUAC increase was associated with a mean rise in systolic BP of 7.19 mmHg in males and 3.18 mmHg in females, respectively. No relationship was found between diastolic BP and WC or MUAC.

Lastly (**Fig. 1**), the majority of hypertensive children (i.e. subjects with systolic BP and/or diastolic BP persistently > 95th percentile as established by Italian paediatric BP tables [20]) presented a WC between 81-105 cm (fifth quintile). A linear trend increase in the percentage of hypertensive children was found across quintiles of WC (chi-squared analysis for linear trend: p = 0.0001). On the contrary (**Fig. 2**), the main percentages of subjects with systolic and/or diastolic BP > 95th percentile featured a MUAC between 20.3-23.6 cm and between 23.7-26.6 cm (second and third



**Figure 1.** Percentages of hypertensive children across the quintiles of WC (statistical test: chi-squared analysis for linear trend).



**Figure 2.** Percentages of hypertensive children across the quintiles of MUAC (statistical test: chi-squared analysis for linear trend).

quintile, respectively). In this case, no linear trend increase in the percentage of hypertensive children was found across quintiles of MUAC (p = ns).

## Discussion

To date, very few paediatric studies have been performed to ascertain which anthropometric measurements are better suited to use in screening for a correlation with elevated BP [6, 17]. To our knowledge the SHARP study is one of the few long-term surveys investigating the association between BP and anthropometric measurements to be conducted in Southern Europe, and certainly the first in Italy [4, 28].

### BMI and blood pressure

It provides confirmation of the previously reported highly significant relationship between BMI and BP, both in OW and normal weight children [3, 4]. However, BMI does not account for the wide variation of body fat distribution, BMI constituting an index of total body fat adiposity, contrary to WC, an index of central adiposity, and MUAC, an index of peripheral adiposity.

### WC, MUAC and blood pressure

The novelty of the SHARP study is represented by the previously unreported comparison between WC and MUAC in influencing BP in children, irrespective of BMI. Additionally, in the specific longitudinal regression analysis used, the marked relationship between WC and BP was confirmed over time. To our knowledge, a previous study performed on patients in a different age range (6-11 years) evaluated the potential association between WC and BP in Southern Italian youths, on the basis of a single recording [29]. A recent study carried out in Germany showed an association of WC with BP [30]. Indeed, both the different body size and pattern of body fat distribution of Northern European children compared with those from Southern Europe, together with use of non-specific population references of paediatric BP, might have influenced the results [18, 31]. Another recent research carried out in Italy showed that WC improved the ability of BMI to identify hypertension in obese children [32]. The SHARP study confirms that WC is related to BP values in all weight classes. In addition, it suggests that even when excluding the effect of BMI, WC is the best anthropometric determinant of systolic BP.
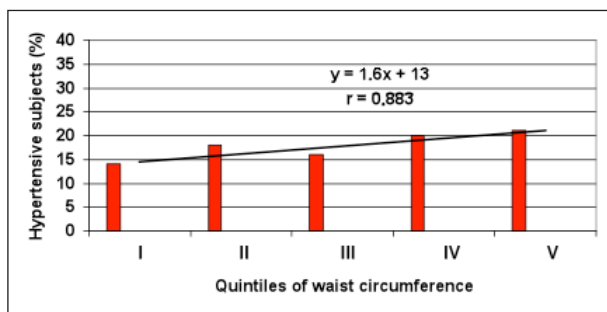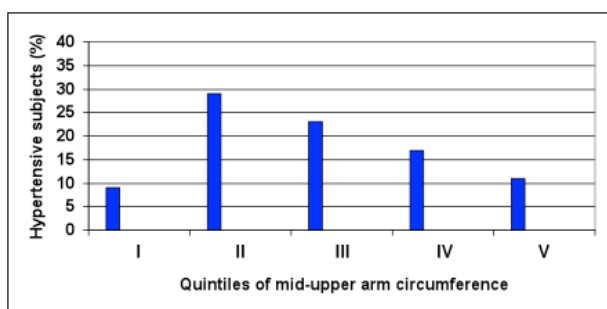
As stated above, correlation with systolic BP is stronger for WC than for MUAC. Furthermore, our findings suggest that the relationship between systolic BP and WC is a little stronger in boys, while the correlation between systolic BP and MUAC is a little more marked in girls. Both associations seem to be related to different body fat distribution in the two genders, main fat deposition being of an abdominal (central) nature in males and peripheral in females [33, 34]. In previous studies, WC – a more accurate tool for measuring android obesity – was found to constitute an independent risk factor for BP in males, and to a lesser degree in females. Hormonal regulators of adipose tissue, including growth hormone, are likely related to gender differences [8, 34, 35].

On the other hand, in recent years, an increase of mean MUAC has been observed in children and adolescents, becoming increasingly evident in adolescent females [36]. To define adolescence in the present study, the 398 girls included in the study, with one exception, reported onset of menarche up to the age of 13 years. As a general rule, transition to maturity in southern European youths is earlier than in those from North Europe. The lack of difference in mean MUAC between genders is due to the fact that in MUAC of males muscle mass is in the majority in comparison with fat. The contrary in females. Mean circumferences are similar, not tissue composition. MUAC is a combination of fat and muscle mass. The latter has a negative effect on blood pressure. The proportion of muscle mass is greater in males, and this is why the relationship of MUAC with systolic BP in males is a little weaker than in females, which have a greater component of fat in their upper arm.

*Anthropometric measures and hypertension*

In the SHARP study the highest percentages of hypertensive subjects were comprised in the higher WC quintile (81-105 cm) and central MUAC quintiles (20.3-23.6 cm and 23.7-26.6 cm, respectively). In other words, contrary to WC, the increasing trend observed between systolic BP and MUAC was significant only for normal BP values, but not for values indicating hypertension. The latter was likely due to high BP being determined increasingly by abdominal (particularly visceral and not subcutaneous fat) than by peripheral fat. A common inflammatory stress condition associated with deposition of abdominal fat may be implicated in development of early stages of proatherosclerotic inflammatory processes and subsequent vascular dysfunction [37]. Neuroendocrine abnormalities have also been identified in abdominally obese children [38].

An involvement of the autonomic nervous system in the above processes is particularly feasible. Enhanced activity of the sympathetic nervous system underlies the development of a number of cardiovascular diseases, including hypertension, by inducing vasoconstriction, increasing cardiac output and promoting renal tubular sodium reabsorption [39, 40]. The SHARP study revealed a significant trend of faster resting HR across WC quintiles, thereby suggesting the presence of a higher sympathetic tone [41].

Noradrenaline spillover was significantly higher in males than in females and was positively related to WC, suggesting that body fat distribution is an important determinant of sex differences in sympathetic activity, particularly at a young age [42]. Sex differences observed in sympathetic neural activity may be explained at least in part by the different gender-related pattern of fat distribution [43].

## Conclusions

In adolescence WC and MUAC are particularly effective as anthropometric determinants of normal systolic BP, irrespective of BMI, although hypertension correlated with WC alone.

Accordingly, increase in WC in childhood should be checked regularly by means of an inexpensive, easy-to-perform measurement and kept within an ideal range in order to contribute towards preventing elevated systolic BP.

Lastly, other not anthropometric factors potentially influencing blood pressure (lipids, lipoproteins, hormones, metabolic profile) should be studied by means of innovative, and extremely promising methods such as metabolomics [44, 45].

## List of abbreviations

BP: blood pressure

OW: overweight

BMI: body mass index

WC: waist circumference

MUAC: mid-upper arm circumference

SHARP: Sardinian Adolescent Research Programme study

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## Declaration of interest

The Authors declare that they have no competing interests.

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