



# Blood Pressure Percentiles in Turkish Children and Adolescents

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## ABSTRACT

**Aim:** Pediatric hypertension, a public health concern, is now commonly known worldwide to be an early risk factor for cardiovascular and renal morbidity and mortality. Early detection of hypertension is of the utmost importance to help reduce serious complications. Several distributions of country-specific blood pressure (BP) percentiles have been established worldwide. The aim of this study is to determine BP percentiles in healthy Turkish children aged 2 to 18 years.

**Materials and Methods:** In this cross-sectional study, BP was measured in 4,984 randomly selected children and adolescents aged 2-17 years. The 50<sup>th</sup>, 90<sup>th</sup> and 95<sup>th</sup> percentile of BP percentiles were determined for gender, age and height with the use a polynomial regression model. BP percentiles at median height were compared with the US Fourth Report references.

**Results:** The normative values of systolic blood pressure (SBP) and diastolic blood pressure (DBP) increased with age for both genders and varied by gender. At median height, the age-specific differences at the 90<sup>th</sup> percentile of SBP tended to be higher in boys than in girls at all ages. DBP values in girls were higher than in boys until the age of 9 years, after which boys demonstrated higher values compared to girls.

**Conclusion:** The age and height specific reference BP values determined in this study is a novel reference for Turkish children and adolescents. Turkish BP values are lower than existing US reference values.

**Keywords:** Blood pressure percentiles, children, height Z-score

## Introduction

Pediatric hypertension, a public health concern, is now commonly known worldwide to be an early risk factor for cardiovascular and renal morbidity and mortality. Children with higher blood pressure (BP) are more likely to become hypertensive adults (1). Measuring BP is a part of physical examination in pediatric clinical practice and its significance had not been understood until recently. Since early detection of hypertension is of the utmost importance to help reduce various complications, BP assessment is now considered as

an essential part of routine physical examination above 3 years of age (2). Elevated BP in children and adolescents is usually defined based on the distribution of BP in a reference population. The BP percentiles used in adults to define hypertension (>140/90 mmHg) is not applicable in the pediatric age group because BP is affected by age, gender and height in children (3).

BP percentile curves were first published in 1987 and described age specific distributions of systolic blood pressure (SBP) and diastolic blood pressure (DBP) for

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an age range between 5 and 17 years, with corrections for height and weight (4). An updated Report from the task force, published in 1996, provided additional details in infants and children (5). In 2004, the Fourth Report added further information including data for overweight and obese children and adapted data to growth charts previously developed by the Centers for Disease Control and Prevention (6). The inclusion of overweight and/or obese children in the normative BP values might lead to values as high as those that are used to define higher than normal BP in adults being considered as normal BP for children. The reference values of the Fourth Report are widely used in the US and European countries. In the Fourth Report, normal BP was defined as SBP and DBP values <90<sup>th</sup> percentile (on the basis of age, gender and height percentiles). For the preadolescent, prehypertension was defined as SBP and DBP ≥90<sup>th</sup> percentile and <95<sup>th</sup> percentile. Hypertension was defined as SBP and DBP ≥95<sup>th</sup> percentile (6). However, definitions of BP categories and stages have been updated in the new guideline of American Academy of Pediatrics for high BP in children and adolescents (7).

The BP values in children show diversity according to countries and, therefore many countries have begun to publish their own reference tables based on their population (8-14). The pooled BP reference values of six European studies have shown relatively high BP in comparison to US children (15).

A study conducted in Italy reported that the normal BP values in Italian children and adolescents were lower than US children and children in other European countries (8). The height-specific BP reference values for non-overweight Chinese children are lower than US reference values (16).

The BP reference values in Turkish children were conducted nearly 15 years ago (17). As secular trends of growing children will affect the normative values of BP, BP reference values should be updated. The aim of this study is to determine BP percentiles in healthy Turkish children aged 2 to 18 years.

## Materials and Methods

This cross-sectional study was performed in 10 schools and nurseries (4 nurseries, 4 elementary schools and 2 high schools) in the selected urban location of İzmir in Turkey with a population of 73,908 individuals aged 2 to 17 years between 2012-2013. The population in this region has low and/or fair socio-economic status. A stratified random cluster sampling method was used to select the children. The minimum sample size was calculated as 3,456 children.

A total of 5,417 children were enrolled, with a response rate of 92% (4,984 children). The children were healthy with no acute or chronic diseases. All measurements were performed by physicians and trained nurses. Weight to the nearest 0.1 kg and height to the nearest 0.1 cm were measured using a Calibrated Electronic scale (SECA, Birmingham, United Kingdom) and a Stadiometer (Harpender stadiometer; Holtain Ltd, Crymmych, United Kingdom). BP was measured with an oscillometric device using the right arm at the level of the heart and choosing a proper cuff size, which had to cover 80%-100% of the arm circumference and width of approximately 40% of the arm length. After at least 5 minutes of rest in the sitting position, three readings of BP for each child were taken with an interval of 2 minutes between readings. Korotkoff phase 1 and Korotkoff phase 5 were used for defining SBP and DBP (12).

The average of the three measurements was used for the analysis. Body Mass Index was calculated as the ratio of weight (kg) by height squared (m<sup>2</sup>). We used the US Fourth Report as the source for all threshold values (6).

The study was approved by the Ethical Committee of Ege University and by the provincial education directorate. Informed written consent was obtained from all parents and from those adolescents aged 13 years and older.

## Statistical Analysis

The polynomial regression model was applied to estimate BP percentiles in relation to gender, age and height by the equation via R version 3.0.2.

$$BP_i = \sum_{j=1}^4 \beta_j (age_i - 10)^j + \sum_{k=1}^4 \gamma_k (Zheight_i)^k + \sum_{k=1}^4 \gamma_k (Zweight_i)^k + e_i$$

A fourth-degree polynomial model was used to predict adjusted BP as a function of age and height Z-score (Zht) for both sexes separately. In the second stage, BP percentiles were constructed after excluding overweight children (>90<sup>th</sup> percentile) because of the possible influence of excess weight on BP distribution, and BP nomogram were refined using the normative database of non-overweight children using the equation.

$$BP_i = \sum_{j=1}^4 \beta_j (age_i - 10)^j + \sum_{k=1}^4 \gamma_k (Zheight_i)^k + e_i$$

## Results

The study population consisted of 2,498 (50.1%) boys and 2,486 (49.1%) girls. We found that the values of SBP

and DBP increased with age for both genders and varied by gender. At median height, the age-specific differences in the 90<sup>th</sup> percentile of SBP tended to be higher in boys than in girls at all ages. The differences of SBP ranged from 0 to 3 mmHg until the age of 13 years and ranged from 2 to 7 mmHg for individuals >13 years old. However, the DBP percentile in boys was higher than in girls by up to 2-4 mmHg in the age group of 2-3 years, after which girls demonstrated higher values by up to 1-3 mmHg compared to boys between the ages of 4-8 years. DBP percentiles were higher in boys after 8 years old by up to 1-65 mmHg.

Table I and Table II shows the corresponding age- and height-specific SBP and DBP percentile values in boys and girls.

Figure 1 and 2 shows the 90<sup>th</sup> percentile of SBP and DBP in boys and in girls by age and percentile of height (height Z-score).

## Discussion

The present study provides normative age and height-specific SBP and DBP values in Turkish children in the age range 2-17 years. We used the same statistical method as the Fourth Report, and we created BP percentiles based on the reference values of the US references. The advantage of this model is that although the distribution of height varies greatly with age, the distribution of Zht does not. Different statistical methods are used to determine BP percentiles in children (18,19).

We found that the SBP and DBP levels of the 90<sup>th</sup> percentiles in Turkish children and adolescents are lower than the US Fourth Report BP references. At median height, the age specific differences in the 90<sup>th</sup> percentiles for SBP in boys and girls were lower by up to 6-13 mmHg and 6-11 mmHg, respectively, and for DBP by up to 1-8 mmHg and 3-7 mmHg, respectively compared with the US references. The present study also included overweight children, as did the Fourth Report. However, the percentage of the overweight children is low. We found that the BP reference values were not influenced by the prevalence of overweight children.

In a study carried out in eight European countries including children (overweight and non-overweight) aged 2 to 10.9 years, SBP and DBP percentiles in boys and girls were higher than our study population for the same age group (12).

In a national study from Turkey in children from birth to 18 years carried out in 1999, the mean SBP and DBP values showed similar values with the results reported in the study of the second task force with small difference (17).

The growth charts for boys and girls were updated in 2006 (20). Therefore, new BP curves for both genders in Turkish children should be determined.

According to data on BP from seven large nationally representative cross-sectional surveys in children aged 6-17 years of age in China, India, Iran, Korea, Poland, Tunisia, and USA published by Xi et al. (14), SBP and DBP reference values in boys and girls from a similar age group were higher than those the present study. The difference between BP percentiles may be due, in part, to the fact that Xi et al. (14) study excluded overweight/obese children while our study included overweight children. In addition, different statistical models were used for these two studies. The authors found similar BP percentiles to the revised US Fourth Report.

In German children, the normal-weight percentiles are nearly identical with the overall growth charts. However, at the 90<sup>th</sup> percentile, the authors found among 17-year-old adolescents 1/1 mmHg higher values in overall than in normal-weight males and females corresponding with 1/1 mmHg in male and 1/3 mmHg in females US adolescents (21). The authors found very small differences between normal-weight German and US children. This suggests that separate growth charts for normal-weight youths are not necessary. The comparison of the overall percentiles from the United States, Poland and Germany demonstrates very similar values (21,22).

A study conducted in Tehran by Ataei et al. (23) compared the 95<sup>th</sup> percentile of BP values of surveys from seven countries including Turkey. The SBP rose progressively with age in both genders, with the rise being steeper among boys after the age of 13. The DBP curves show slight differences between the two genders. British and Saudi Arabian children present the highest SBP levels for both genders compared to other countries with minor differences compared to each other until the age of 13, where their curves start to diverge and the data from the UK remains higher. Up to the age of six, Iran has the lowest BP levels among these countries for both genders. Saudi Arabia has the highest levels in almost all ages for both genders, while the Iranian DBP curve presents the lowest DBP levels. British DBP levels present with a mostly horizontal line until it becomes the lowest after the age of 13 years.

Raj et al. (24) reported that the BP normative values in Indian children aged 5-16 years demonstrated a different pattern in comparison to the US data. BP percentiles of Indian schoolchildren have higher DBPs for both genders than the Fourth Report reference. For SBP, girls showed

**Table I.** The percentiles of systolic and diastolic blood pressure in boys by age and percentile of height

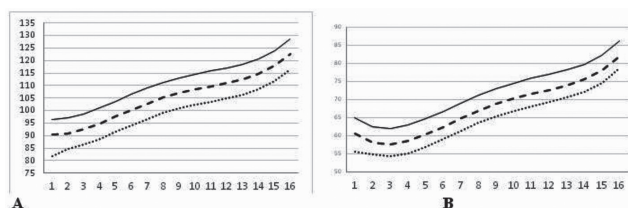
Age (year)	H*	0.05 p	0.25 p	0.50 p	0.75 p	0.95 p	0.05 p	0.25 p	0.50 p	0.75 p	0.95 p
	BP**										
2	0.50	79	85	85	89	92	53	57	58	59	65
	0.90	82	88	90	92	97	56	59	60	62	69
	0.95	85	89	91	93	98	56	60	61	63	70
3	0.50	80	87	89	90	91	52	56	57	58	63
	0.90	85	89	91	93	97	53	57	58	59	67
	0.95	85	89	92	93	98	54	57	58	60	68
4	0.50	83	89	91	93	93	52	56	57	58	63
	0.90	86	91	93	94	99	53	57	57	59	66
	0.95	87	91	93	95	100	53	57	58	59	67
5	0.50	86	92	94	95	96	53	57	58	59	64
	0.90	89	93	95	97	101	54	57	58	60	67
	0.95	89	93	95	97	102	54	58	58	60	68
6	0.50	89	95	97	98	99	55	59	60	61	66
	0.90	92	96	98	99	104	55	59	60	62	69
	0.95	92	96	98	100	104	55	59	60	62	69
7	0.50	92	98	100	101	102	57	61	62	63	68
	0.90	94	98	100	102	106	57	61	62	64	71
	0.95	94	98	100	102	107	57	61	62	64	71
8	0.50	94	101	103	104	105	59	63	64	65	70
	0.90	97	101	103	105	109	60	64	64	66	73
	0.95	97	101	103	105	110	60	64	64	66	74
9	0.50	96	103	105	106	107	61	66	66	68	72
	0.90	99	103	105	107	111	62	66	66	68	75
	0.95	99	103	105	107	112	62	66	66	68	76
10	0.50	98	105	107	108	109	63	67	68	69	74
	0.90	101	105	107	109	113	63	68	68	70	77
	0.95	101	105	107	109	114	64	68	68	70	78
11	0.50	99	106	108	109	110	65	69	69	71	76
	0.90	102	106	108	110	115	65	69	70	71	78
	0.95	102	106	109	110	115	65	69	70	72	79
12	0.50	100	107	109	110	111	66	70	70	72	77
	0.90	104	108	110	111	116	66	70	71	73	80
	0.95	104	108	110	112	117	66	70	71	73	80
13	0.50	101	108	110	111	112	66	71	71	73	78
	0.90	105	109	111	113	117	67	71	72	74	81
	0.95	105	109	111	113	118	68	72	72	74	82
14	0.50	102	109	111	112	113	67	71	72	73	78
	0.90	106	110	112	114	119	69	73	73	75	82
	0.95	107	111	113	115	120	69	73	74	76	83
15	0.50	103	110	112	113	114	68	72	73	74	79
	0.90	108	113	115	116	121	70	74	75	77	84
	0.95	109	113	115	117	122	71	75	75	77	85
16	0.50	105	112	114	115	116	70	74	75	76	81
	0.90	112	116	118	120	124	73	77	77	79	86
	0.95	113	117	119	121	125	73	78	78	80	87
17	0.50	108	115	117	118	119	72	77	77	79	83
	0.90	116	121	123	124	129	76	81	81	83	90
	0.95	118	122	124	126	131	77	82	82	84	91

H\*: Height of 5<sup>th</sup>, 25<sup>th</sup>, 50<sup>th</sup>, 75<sup>th</sup> and 95<sup>th</sup> percentiles, BP\*\*: Blood pressure

**Table II.** The percentiles of systolic and diastolic blood pressure in girls by age and percentile of height

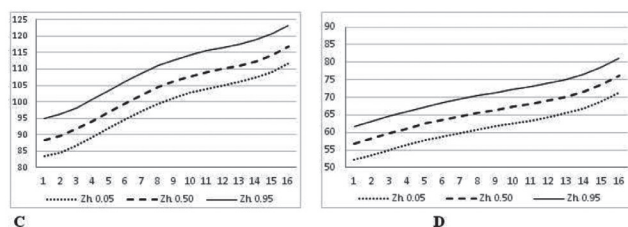
Age (year)	H* BP**	SBP					DBP				
		0.05 p	0.25 p	0.50 p	0.75 p	0.95 p	0.05 p	0.25 p	0.50 p	0.75 p	0.95 p
		2	0.50	81	82	84	87	91	50	51	53
	0.90	83	86	87	89	95	52	54	56	58	62
	0.95	84	87	88	90	96	53	55	57	59	63
3	0.50	83	84	87	89	93	52	54	56	58	60
	0.90	85	87	89	90	96	54	55	57	60	63
	0.95	85	88	89	91	97	54	56	58	60	64
4	0.50	86	87	89	92	96	54	56	58	60	63
	0.90	87	89	91	92	98	55	57	59	61	65
	0.95	87	90	91	93	99	55	57	59	62	65
5	0.50	89	90	92	95	99	56	58	59	62	64
	0.90	89	92	93	95	101	56	58	60	63	66
	0.95	89	92	93	95	101	57	58	60	63	67
6	0.50	92	93	95	98	102	57	59	61	63	66
	0.90	92	95	96	97	104	58	59	61	64	67
	0.95	92	95	96	98	104	58	60	62	64	68
7	0.50	95	96	98	101	105	59	60	62	64	67
	0.90	95	97	99	100	106	59	61	63	65	68
	0.95	95	97	99	100	107	59	61	63	65	69
8	0.50	97	99	101	104	107	60	61	63	65	68
	0.90	97	100	101	103	109	60	62	64	66	70
	0.95	97	100	101	103	109	60	62	64	66	70
9	0.50	99	101	103	106	110	61	62	64	66	69
	0.90	99	102	103	105	111	61	63	65	67	70
	0.95	99	102	103	105	111	61	63	65	67	71
10	0.50	101	103	105	108	111	62	63	65	67	70
	0.90	101	104	105	107	113	62	63	65	68	71
	0.95	101	104	105	107	113	62	63	66	68	72
11	0.50	103	104	106	109	113	62	64	66	68	71
	0.90	103	105	107	108	114	63	64	66	69	72
	0.95	103	106	107	108	115	63	64	66	69	73
12	0.50	103	105	107	110	114	63	65	66	69	71
	0.90	104	107	108	109	116	63	65	67	69	73
	0.95	104	107	108	110	116	64	65	67	70	73
13	0.50	104	106	108	110	114	64	65	67	69	72
	0.90	105	108	109	110	117	64	66	68	70	74
	0.95	105	108	109	111	117	65	66	68	71	75
14	0.50	105	106	108	111	115	64	66	68	70	73
	0.90	106	109	110	111	118	65	67	69	72	75
	0.95	106	109	111	112	118	66	68	70	72	76
15	0.50	105	106	109	111	115	65	66	68	70	73
	0.90	107	110	111	113	119	67	69	71	73	77
	0.95	108	111	112	114	120	68	69	71	74	78
16	0.50	106	107	109	112	116	66	67	69	71	74
	0.90	109	112	113	115	121	69	71	73	75	78
	0.95	110	113	114	116	122	70	72	74	76	80
17	0.50	107	108	110	113	117	67	68	70	72	75
	0.90	112	114	116	117	123	71	73	75	77	81
	0.95	113	116	117	119	127	73	74	77	79	83

H\*: Height of 5<sup>th</sup>, 25<sup>th</sup>, 50<sup>th</sup>, 75<sup>th</sup> and 95<sup>th</sup> percentiles, BP\*\*: Blood pressure, SBP: Systolic blood pressure, DBP: Diastolic blood pressure



**Figure 1.** 90<sup>th</sup> percentile of blood pressure in boys by age and percentile of height (height z score)

**A.** Systolic blood pressure; **B.** Diastolic blood pressure



**Figure 2.** 90<sup>th</sup> percentile of blood pressure in girls by age and percentile of height (height z-score)

**C.** Systolic blood pressure; **D.** Diastolic blood pressure

higher values than the Fourth Report reference, while for boys, the difference appears to be minimal.

A reference sample of Chinese children aged 7-17 years from the Chinese Health and National Survey 1991-2009 was compared with the Fourth Report references. The 50<sup>th</sup>, 90<sup>th</sup> and 95<sup>th</sup> percentiles of SBP in boys and girls were on average 9-10 mmHg lower than their American counterparts; however, there were no clear differences in DBP percentiles. These results are consistent with the BP percentiles of our study (16). Whereas a national study obtained by the 2010 National Health Survey in children between 7-17 years of age from China reported that the 50<sup>th</sup>, 90<sup>th</sup>, 95<sup>th</sup> and 99<sup>th</sup> percentiles of BP in boys and girls aged 7 to 13 years were consistent with the US reference (25).

Polish preschool children's 90<sup>th</sup> and 95<sup>th</sup> SBP and DBP percentiles were lower than those in the US and German BP references. Differences in the 95<sup>th</sup> SBP percentiles ranged by age from -5 to 0 mmHg and from -2 to -1 mmHg, in boys and girls, respectively, whereas the difference at the same percentile of DBP ranged from -7 to -1 mmHg and from -5 to -1 mmHg in boys and girls, respectively. However, the 90<sup>th</sup> percentiles of SBP and DBP in Polish preschool children were higher than those for our children (22).

The comparison of data regarding BP percentiles in children from similar studies may be possibly limited by the different BP readings obtained from different automated devices, BP measurement numbers and different statistical methods used. BP normative values can also show differences depending on whether or not overweight

children are included in the study. Furthermore, different patterns of BP percentiles in children and adolescents in different countries may be due to the influence of diverse socio-economic, cultural and nutritional factors in comparison to the US references.

### Study Limitations

The present study has several limitations. Firstly, the reference values are based on BP measurements measured during a single session and not on multiple estimates from at least 3 separate sessions. Secondly, environmental factors were not included because life style data were not available for all subjects who took part in this study. Finally, comparable data from rural areas were not available. Therefore, the generalization of our results is limited.

### Conclusion

We found that the values of SBP and DBP increased with age for both genders and varied by gender. The SBP and DBP levels of the 90<sup>th</sup> percentiles in Turkish children and adolescents are lower than the US BP references. In contrast to the US Fourth Report references, the reference values of the present study are not influenced by the prevalence of overweight children. National BP reference values of Turkish children and adolescents will be useful for international comparisons of national normative BP values and for evaluating the prevalence of elevated BP in children.

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### Ethics

**Ethics Committee Approval:** The study was approved by the Ethical Committee of Ege University and by the provincial education directorate (approval number: 11.12.2013, date: 12.01.2012).

**Informed Consent:** Informed written consent was obtained from all parents and from those adolescents aged 13 years and older.

**Peer-review:** Externally and internally peer-reviewed.

### Authorship Contributions

Concept: A.K., P.K., T.K., Design: A.K., P.K., T.K., Data Collection or Processing: P.K., S.Ö., Analysis or Interpretation: A.K., P.K., S.Ö., T.K., Literature Search: A.K., P.K., S.Ö., T.K., Writing: T.K.

**Conflict of Interest:** None of the authors had conflict of interest.

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