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Percentiles for anthropometric measures in Iranian children and adolescents: the CASPIAN-IV study

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Abstract

Background: The aim of the study was to provide the age- and sex-specific percentile values of anthropometric measures for Iranian children and adolescents.
Methods: This cross-sectional nationwide survey was conducted on a representative sample of 14,880 school students, selected by multistage random cluster sampling from urban and rural areas of 30 provinces in Iran. Anthropometric measures including body mass index (BMI), waist circumference (WC), hip circumference (HC), and wrist circumference were measured under standard protocols by using calibrated instruments. Age- and gender-specific reference values were developed for anthropometric measures by the maximum penalized likelihood approach [Cole's least mean square (LMS) method].
Results: In the present study, 13,486 out of the 14,880 invited subjects completed all the required data of the study (participation rate: 90.6%). Participants consisted of 6640 girls (49.2%) and 75.6% urban residents; their mean and standard deviation (SD) age was 12.47±3.36 years. The BMI percentile curves of girls had a sharp increase from 14 to 18 years, and then began to plateau, but among boys, these curves had a consistent increase until the age of 18 years. In addition, the higher percentiles were higher in adolescent boys than girls. The HC percentile curves of both sexes had a persistent increase and the percentiles for HC were higher in adolescent girls than in boys. WC had a sharp increase from 7 to 18 years of age for boys, whereas for girls, these curves had a less sharp increase with age. In all ages, the percentiles for wrist circumference were higher in adolescent boys than girls.
Conclusions: The findings of this study highlight the necessity of paying special attention to developing age- and gender-specific percentiles of anthropometric measures in children and adolescents.

Keywords: anthropometric percentiles; children and adolescents; waist circumference.

Introduction

Anthropometric parameters provide important information about body composition in the pediatric age group. Anthropometry is the most used and preferred clinical

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tool to follow the normal growth of child at an individual level and for health policy makers [1]. Anthropometric measures might be also helpful in the prediction of non-communicable disease risk factors from childhood [2–4].

Body mass index (BMI) is considered as the most common indicator for obesity screening and cardio-metabolic risk factors [5, 6]. Unlike its wide use, BMI does not distinguish between fat and lean body mass, which might lead to inaccurate information regarding body composition [7]. These limitations of BMI can be partly explained by the measurement of other anthropometric indices, including waist circumference (WC), and hip circumference (HC). Measurement of WC [8–10] or waist-to-height ratio (WHtR) [11, 12] is recommended for evaluating cardio-metabolic risks.

Measurement of the wrist has been proposed as a simple anthropometric index of skeletal frame size, and is found to be related with insulin resistance among obese children and adolescents [13]. Because of its simplicity and easy-to-detect properties, most recently, wrist circumference

Table 1: Characteristics of Iranian children and adolescents by gender: the CASPIAN-IV Study.

	Boys	Girls	Total	p-Value
Living in urban area[a]	74.9 [71.7, 77.8]	76.3 [73.1, 79.1]	75.6 [73.3, 77.7]	0.50
Age[b]	12.4 [12.3, 12.4]	12.6 [12.5, 12.7]	12.5 [12.4, 12.5]	<0.001
Height[b]	148.2 [146.8, 149.5]	145.8 [144.7, 146.7]	147.0 [146.1, 147.9]	<0.001
Weight[b]	43.1 [41.9, 44.2]	41.7 [40.8, 42.7]	42.4 [41.6, 43.2]	<0.001
BMI[b]	18.7 [18.6, 18.8]	18.9 [18.8, 19.0]	18.8 [18.7, 18.9]	0.002
Waist circumference[b]	67.8 [67.5, 68.1]	66.2 [65.9, 66.5]	67.0 [66.8, 67.2]	<0.001
Hip circumference[b]	80.1 [79.7, 80.5]	81.5 [81.1, 81.9]	80.8 [80.5, 81.1]	<0.001
Wrist circumference[b]	15.0 [14.9, 15.1]	14.5 [14.4, 14.5]	14.7 [14.7, 14.8]	<0.001

[a]presented as percent (95% CI). [b]presented as mean (95% CI).

Table 2: Body mass index percentile values for Iranian children and adolescents, by gender and age: the CASPIAN-IV Study.

Age	c3	c5	c10	c25	c50	c75	c85	c90	c95	c97
Boys										
7	12.5	12.7	13.2	13.9	14.9	16.6	18	18.6	20.2	21.5
8	12.6	12.9	13.3	14.1	15.3	17.1	18.6	19.3	21.1	22.6
9	12.8	13.1	13.6	14.4	15.7	17.7	19.3	20.1	22.1	23.7
10	13	13.3	13.9	14.8	16.2	18.4	20.1	21	23.1	24.9
11	13.3	13.7	14.3	15.3	16.8	19.2	21.1	22	24.3	26.2
12	13.7	14.1	14.7	15.8	17.5	20	22	23	25.4	27.4
13	14.1	14.5	15.2	16.4	18.1	20.8	22.9	24	26.5	28.5
14	14.5	15	15.7	17	18.8	21.6	23.8	24.9	27.4	29.5
15	15	15.5	16.2	17.6	19.5	22.3	24.6	25.7	28.4	30.5
16	15.6	16	16.8	18.2	20.2	23.1	25.4	26.6	29.3	31.4
17	16.1	16.5	17.4	18.8	20.8	23.8	26.2	27.3	30	32.2
18	16.5	17	17.8	19.3	21.3	24.4	26.8	27.9	30.6	32.8
Girls										
7	12.4	12.6	13.1	13.9	15	16.7	18	18.9	20.5	21.9
8	12.4	12.7	13.2	14.1	15.3	17.2	18.6	19.6	21.4	23
9	12.5	12.8	13.4	14.4	15.7	17.8	19.3	20.4	22.4	24
10	12.7	13	13.7	14.7	16.2	18.5	20.1	21.3	23.4	25.1
11	13	13.3	14	15.2	16.9	19.3	21.1	22.3	24.5	26.3
12	13.4	13.8	14.6	15.8	17.6	20.3	22.1	23.4	25.7	27.4
13	13.9	14.3	15.2	16.6	18.5	21.2	23.2	24.5	26.8	28.6
14	14.5	15	15.8	17.3	19.3	22.2	24.1	25.5	27.8	29.6
15	15.1	15.6	16.5	18	20	23	25	26.3	28.7	30.4
16	15.6	16.1	17	18.5	20.6	23.6	25.6	26.9	29.2	31
17	16	16.5	17.4	19	21.1	24	26	27.4	29.6	31.3
18	16.4	16.9	17.8	19.4	21.5	24.4	26.4	27.7	29.8	31.4

c, centile.

has been suggested as a new anthropometric measure to predict type 2 diabetes and metabolic syndrome [14]. It has also been suggested as an independent predictor for the incidence of hypertension (HTN) and cardiovascular diseases of non-abdominally obese individuals [15].

Reference charts (values, percentiles) have been established for anthropometric parameters of different areas such as North America [16], Canada [17], Turkey [18], and Australia [19]; however, they might not be applicable for Iranian children. Therefore, the aim of this study is to estimate an update for anthropometric percentiles, as well as to present wrist circumference values in a large nationally representative sample of Iranian children and adolescents.

Materials and methods

This study was conducted in 2011–2012 as part of the fourth survey of the school-based surveillance system entitled "Childhood and Adolescence Surveillance and Prevention of Adult Non-communicable disease (CASPIAN-IV) study". The detailed methodology has been described previously [20]; here, we highlight some topics related to the current study.

Using a multistage cluster sampling method, 14,880 school students were selected from 30 provinces of Iran. As the sampling was proportional to size with equal sex ratios, there were an equal number of boys and girls selected from each province, and the ratios in urban and rural areas were balanced with respect to the population of urban and rural students.

Trained interviewers collected demographic information including age, sex, and living area. A team of trained healthcare professionals and physicians recorded the information and conducted the physical examination under standard protocols by using calibrated instruments. BMI was calculated as weight (kg) divided by height squared (m^2) [21]. WC was measured at the end of breath expiration to the nearest 0.1 cm with a flexible inextensible tape. The modified criteria for children and adolescents consisted of abdominal obesity as WC ≥90th percentile value for age and sex. The maximum level of hip without any pressure to the body surface to the nearest 0.5 cm was considered for measuring the HC. Wrist circumference was measured, with subjects in a seated position, from both wrists distal to the prominences of the radius and ulna and an average was taken.

Statistical analysis

The percentiles were computed in the population studied and were used for the classification of participants as underweight

Table 3: Waist circumference percentile values for Iranian children and adolescents, by age and gender: the CASPIAN-IV study.

Age	c3	c5	c10	c25	c50	c75	c85	c90	c95	c97
Boys										
7	47	48	49.4	51.4	54.6	59	62	64.2	67	67.6
8	47.9	49.2	50.8	53.2	56.9	61.8	65.2	67.8	71.1	72.1
9	49.1	50.4	52.2	55	59.1	64.6	68.4	71.2	75.1	76.3
10	50.4	51.8	53.8	56.9	61.3	67.2	71.4	74.5	78.9	80.5
11	51.8	53.3	55.4	58.7	63.4	69.8	74.3	77.8	82.7	84.6
12	53.2	54.8	57	60.5	65.6	72.4	77.2	80.9	86.4	88.6
13	54.7	56.3	58.6	62.4	67.7	74.9	80.1	84.1	90	92.5
14	56.2	57.9	60.3	64.2	69.8	77.3	82.9	87.1	93.6	96.4
15	57.8	59.5	61.9	66	71.9	79.8	85.6	90.2	97.1	100.3
16	59.4	61.1	63.6	67.8	73.9	82.2	88.4	93.2	100.6	104.2
17	61	62.7	65.3	69.7	76	84.7	91.1	96.2	104.1	108
18	62.6	64.4	67	71.5	78	87.1	93.8	99.2	107.6	111.9
Girls										
7	45.2	46.2	47.8	50.4	53.8	58	60.7	63	65.5	67.5
8	46.5	47.7	49.6	52.7	56.6	61.3	64.5	67.1	70.3	72.7
9	48.1	49.4	51.4	54.7	59	64.2	67.7	70.6	74.2	77
10	49.7	51	53.1	56.7	61.2	66.7	70.5	73.6	77.5	80.6
11	51.4	52.7	54.8	58.4	63.1	68.9	72.9	76.2	80.4	83.7
12	52.9	54.3	56.4	60.1	64.9	70.9	75	78.4	82.9	86.4
13	54.5	55.8	57.9	61.6	66.5	72.7	77	80.5	85.2	88.8
14	55.9	57.2	59.4	63.1	68.1	74.3	78.7	82.4	87.2	91
15	57.3	58.6	60.7	64.4	69.5	75.8	80.3	84.1	89.1	93
16	58.6	59.9	62	65.7	70.8	77.2	81.8	85.6	90.8	94.8
17	59.9	61.1	63.2	66.9	72.1	78.6	83.2	87.1	92.4	96.5
18	61.1	62.3	64.4	68.1	73.2	79.8	84.5	88.5	93.8	98.1

c, centile.

Table 4: Percentile values of hip circumference for Iranian children and adolescents by gender and age: the CASPIAN-IV Study.

Age	c3	c5	c10	c25	c50	c75	c85	c90	c95	c97
Boys										
7	51.1	53.1	55.3	58.6	62.5	67	70.2	72.7	76.6	78.8
8	54.8	56.9	59.1	62.3	66.2	70.7	73.9	76.4	80.1	82.2
9	57.6	59.8	62.1	65.5	69.7	74.4	77.8	80.3	84.2	86.4
10	59.6	62.1	64.8	68.5	73	78	81.6	84.3	88.5	90.8
11	61.3	64.1	67.1	71.3	76.2	81.6	85.4	88.3	92.8	95.2
12	62.9	66	69.3	73.9	79.2	84.9	89	92.1	96.8	99.5
13	64.4	67.8	71.5	76.4	82	88.1	92.4	95.7	100.7	103.4
14	66.2	69.8	73.7	78.9	84.8	91.1	95.6	99	104.1	107
15	68.1	71.9	76	81.4	87.5	94	98.5	102	107.3	110.1
16	70.5	74.3	78.4	83.9	90	96.6	101.2	104.7	110	112.8
17	73.3	77.1	81.1	86.5	92.5	99.1	103.6	107.1	112.3	115
18	76.6	80.3	84	89.1	95	101.3	105.8	109.1	114.1	116.7
Girls										
7	52.1	54	56.2	59.5	63.4	67.7	70.5	72.7	75.9	78.7
8	54.2	56.3	58.9	62.7	67.2	72	75.2	77.7	81.3	84.4
9	56.7	59	61.8	65.8	70.7	75.9	79.3	82	85.9	89.2
10	59.2	61.7	64.6	68.9	74.1	79.6	83.1	86	90.1	93.5
11	61.9	64.4	67.5	71.9	77.3	83	86.7	89.6	93.8	97.4
12	64.5	67.1	70.3	74.8	80.3	86.2	90	93	97.4	101.1
13	67.2	69.8	73	77.7	83.2	89.2	93.1	96.2	100.7	104.5
14	69.8	72.5	75.7	80.4	86	92.1	96.1	99.2	103.8	107.7
15	72.3	75	78.3	83	88.7	94.9	98.9	102.1	106.7	110.7
16	74.8	77.6	80.9	85.6	91.4	97.5	101.6	104.9	109.6	113.6
17	77.3	80.1	83.4	88.1	93.9	100.1	104.2	107.5	112.3	116.4
18	79.7	82.5	85.8	90.6	96.4	102.6	106.8	110.1	114.9	119.1

c, centile.

(<5th percentile), normal (5th–84th percentile), overweight (85th–94th percentile), and obese (≥95th percentile) [22, 23].

Continuous variables are reported as mean, 95% confidence interval (95%CI); categorical variables are reported as a percentage (95%CI). To be comparable with other studies, the 3rd, 5th, 10th, 25th, 50th, 75th, 85th, 90th, 95th, and 97th percentiles were selected as reference values. Smoothed age- and gender-specific values and charts for each percentile value and for each anthropometric index were derived using the least median of squares (LMS) regression.

Cole's LMS method, also called the maximum penalized likelihood approach, was used because it is documented to be a powerful and compact technique for deriving and presenting reference charts. It calculates the Box-Cox power needed to transform the data to normality at each age, and displays the results as a smooth curve of power plotted against age, allowing the original percentiles to be reconstructed to high accuracy. The software LMS Pro was used for data management which was obtained from the Institute of Child Health, London, UK. The Stata Statistical Software Package (release 12, StataCorp LP, College Station, TX, USA) was used for analyzing date, and a p-value <0.05 was considered to be statistically significant.

Ethical consideration

Ethical committees and other relevant regulatory organizations reviewed and approved the study at the national and provincial levels. Participation in the present study was voluntary. For moral consideration, the objectives and methods of the study were described to all the participants, and written informed consent and oral assent were obtained from all the parents and students, respectively, who consented to participate.

Results

Measurements obtained from 13,486 students were used in this analysis (participation rate of 90.6%). They consisted of 6640 girls (49.2%) and 6846 boys (50.8%); 75.6% and 24.4% of the students were from urban and rural areas, respectively. The mean age of the participants was 12.47 (12.41–12.53) years, with a significant difference between boys [12.36 (12.28–12.44)] and girls [12.58(12.50–12.66)] ($p<0.001$).

Characteristics of the study participants, stratified by sex, are given in Table 1. Except for HC, other anthropometric measures including height, weight, WC, and wrist circumference were significantly higher in boys than in girls ($p<0.001$). BMI had no significant difference between boys and girls.

Tables 2–5 show the smoothed percentile values for BMI, WC, HC, and wrist circumference by age and sex. By considering BMI, among 7 year old boys, 12.7% were underweight (<5th percentile) and 2.2% were overweight (85th–94th percentile). The corresponding figures for girls were 13.08% and 0.24%, respectively.

Figure 1 shows the smoothed reference curves of BMI, WC, HC and wrist circumference for the 5th, 10th, 25th, 50th, 75th, 85th, 90th, and 95th percentile in both sexes. The BMI percentile curves of girls had a sharp increase from 14 to 18 years, and then began to plateau, but among boys, these curves had a consistent increase until the age of 18 years. In addition, the higher percentiles were higher in adolescent boys than girls. The HC percentile curves of both sexes had a persistent increase and the percentiles for HC were higher in adolescent girls than in boys. WC had a sharp increase from 7 to 18 years of age for boys, whereas for girls, these curves had a less sharp increase with age. In all ages, the percentiles for wrist circumference were higher in adolescent boys than girls.

Discussion

This study was conducted to provide age- and gender-specific percentile curves for anthropometric indices. Development of reference curve standards is usually used as a screening tool to identify childhood growth disorders [24]. We found that anthropometric values including height, weight, WC, and wrist circumference were significantly higher in boys than in girls.

To the best of our knowledge, this study is the first to provide nationally representative percentile values for wrist circumference for a pediatric population in the Middle East and North Africa (MENA). It has been indicated that wrist circumference is relatively easy to measure, and can be considered as a novel predictor for pre-diabetes and the further development of diabetes and metabolic syndrome of adults [14]. Various anthropometric percentile curves have already been established; however, there are few studies about wrist circumference with children and adolescents as a target group [23].

Table 5: Percentile values of wrist circumference for Iranian children and adolescents by sex and age: the CASPIAN-IV study.

Age	c3	c5	c10	c25	c50	c75	c85	c90	c95	c97
Boys										
7	11	11.2	11.5	12	12.6	13.5	14	14.4	15.1	15.7
8	11.2	11.5	11.8	12.3	13	13.8	14.4	14.8	15.5	16.1
9	11.5	11.7	12.1	12.6	13.4	14.3	14.8	15.2	15.9	16.5
10	11.8	12	12.4	13	13.8	14.7	15.2	15.7	16.3	16.9
11	12.1	12.4	12.7	13.4	14.2	15.2	15.7	16.2	16.8	17.4
12	12.4	12.7	13.1	13.9	14.7	15.7	16.3	16.7	17.4	18
13	12.8	13.1	13.5	14.3	15.2	16.2	16.8	17.3	17.9	18.6
14	13.2	13.5	14	14.8	15.7	16.8	17.4	17.8	18.5	19.1
15	13.6	14	14.4	15.3	16.2	17.3	17.9	18.4	19	19.7
16	14	14.4	14.8	15.7	16.6	17.7	18.3	18.8	19.4	20.1
17	14.3	14.7	15.1	16	16.9	18	18.6	19.1	19.7	20.4
18	14.6	15	15.4	16.2	17.2	18.2	18.9	19.3	20	20.6
Girls										
7	10.7	10.9	11.2	11.8	12.4	13.2	13.8	14.1	14.8	15.3
8	11.1	11.3	11.6	12.2	12.8	13.6	14.2	14.6	15.2	15.7
9	11.4	11.7	12	12.6	13.2	14.1	14.6	15	15.7	16.1
10	11.8	12	12.4	13	13.6	14.5	15.1	15.4	16.1	16.5
11	12.2	12.4	12.7	13.3	14	14.9	15.5	15.8	16.5	16.9
12	12.5	12.7	13.1	13.7	14.4	15.3	15.8	16.2	16.9	17.3
13	12.8	13	13.4	14	14.7	15.6	16.2	16.5	17.2	17.6
14	13	13.3	13.6	14.3	15	15.9	16.5	16.8	17.4	17.8
15	13.2	13.5	13.8	14.5	15.2	16.1	16.7	17	17.6	18
16	13.3	13.6	14	14.7	15.4	16.3	16.8	17.2	17.7	18.1
17	13.4	13.7	14.1	14.8	15.6	16.4	17	17.3	17.8	18.2
18	13.5	13.8	14.3	15	15.7	16.5	17.1	17.4	17.9	18.2

c, centile.

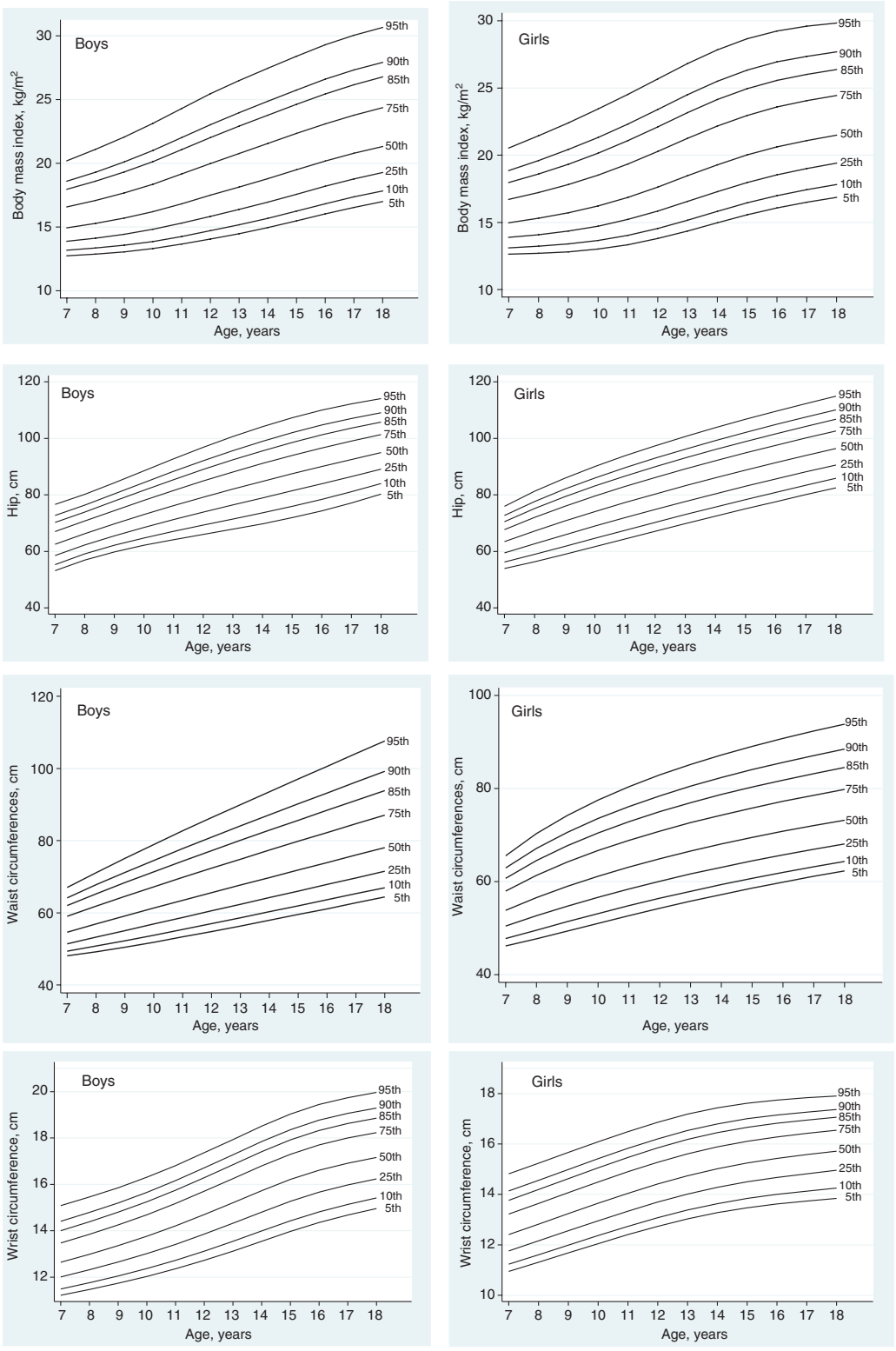

Figure 1: Age- and gender-specific smoothed reference curves of body mass index, hip, waist, and wrist circumferences of a national sample (n=13,486) of Iranian children: the CASPIAN-IV Study.

Measurement of wrist circumference, as a good anthropometric parameter and a simple and well-known index of skeletal frame size, could provide additional information regarding the body composition of children and adolescents. The previous results showed that wrist circumference is a better predictor of insulin resistance and levels

of triglycerides among overweight/obese children and adolescents compared to the BMI standard deviation score [13]. In the follow-up of a West Asian cohort, this index could also be assumed to act as a predictor of non-communicable disease, including hypertension and cardiovascular disease among non-centrally obese women [15].

The wrist circumference index is accessible and easily measurable by physicians; moreover, its reproducibility is higher than WC. Although measurement of WC is common, there is no unique acceptable measurement protocol, leading to different techniques in the literature [25, 26]. Thus, because of the high collinearity between these two parameters, wrist circumference could possibly be used to categorize obese individuals and for the prediction of insulin resistance and, subsequently, cardiometabolic risk [13].

Our findings are consistent to previous studies in which some anthropometric measures such as BMI, WC, and HC in Iranian boys were higher than in girls [27]. It might be partly explained by gender differences, in which girls are more likely to look slim while boys usually prefer increased muscle mass and body weight [27].

In the present study, underweight, overweight and/or obese were documented among Iranian students representing the double burden of nutritional disorders [28]. This finding is in line with previous reports [29–31]. Some underlying factors, including fast urbanization, physical inactivity, and unhealthy dietary patterns with low-nutrient high density foods, might play a role [28].

Previous studies have demonstrated that an increased mortality rate due to increased body fat might be because of abdominal obesity [32]. Measurement of WC has been recognized as a highly sensitive and specific index of upper body fat deposition that correlates with insulin resistance in adult population [33]. WC is applicable for clinical screening. WC reference values might differ between countries and even in different parts of a country, due to variations in genetic and environmental factors, including physical activity and dietary habits [33]. WC percentile references have been previously developed for children and adolescents living in Australia [34], Canada [35], Italy [36], the Netherlands [37], Turkey [38], and the UK [39].

In the present study, with increase in age, WC and HC values increased in both genders, with higher WC values in boys. This finding is similar to previous studies conducted in Malaysia [40], Bulgaria [10], and Venezuela [41], and represent the normal growth pattern during childhood.

Several characteristics of the present study make the results valuable and reliable. These data represent a large nationwide sample of students across the country, in which both genders and urban/rural inhabitants participated in the study, following a standard protocol, and using the same measurement techniques by trained healthcare professionals. However, due to the large sample size, examination of pubertal stage and its effects on anthropometric indices were not possible.

These results could provide the wrist circumference percentile as a convenient, inexpensive, applicable, and non-invasive measure to evaluate frame size and body composition of children. Furthermore, an update of other anthropometric values might improve the interpretation of anthropometric indices in medical examinations, as well as an individual assessment of child nutritional status and public health screening. Future national and international epidemiologic comparisons will also be feasible.

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