First Reference Curves of Waist and Hip Circumferences in An Asian Population of Youths: CASPIAN Study

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Summary

The Objective of the present study is to develop the first age- and gender-specific reference curves for waist and hip circumferences in an Asian population of youths. This cross-sectional population survey was conducted in 2003–04 on a nationally representative sample of 21111 school-students living in urban (84.6%) and rural (15.4%) areas of 23 provinces in Iran. After anthropometric measurements, smoothed reference curves for waist and hip circumference (WC, HiC) and waist-to-hip ratio (WHR) were developed by the LMS method. In both genders, WC and HiC percentile values increased with age. For girls, the 50th to 95th percentile curves for WC had a sharp increase between 8 and 13 years and 11–15 years, respectively, and began to plateau after this age, whereas for boys, these curves had a persistent and less sharp increase with age, until the age of 18 years. The WHR curves of girls decreased with age until 15 years and began to plateau thereafter, whereas for boys the 25th to 95th curves had a plateau pattern. Comparison of the current reference curves with the British ones showed that in boys, the 5th and 50th percentile curves were similar in both studies, but the 95th percentile curve of our study was higher than the British curves. For girls, the 5th percentile curves of both studies were similar, but the 50th and 95th percentile curves of our study were higher than the British ones. These curves represent the first childhood WC, HiC and WHR reference curves obtained in Asia. These curves can provide baseline data for analysis of time trends, as well as for international comparisons.

Key words: reference curve, waist circumference, hip circumference, waist-to-hip ratio, Asian, youths.

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Introduction

There is abundant documentation in developing countries on the burden of noncommunicable diseases (NCDs) [1]. In addition, it is suggested that Asians have an ethnic predisposition to metabolic syndrome [2]. Interest in childhood precursors to chronic diseases is increasing because it is well documented that both behavioral and biological risk factors of such diseases persist from childhood into adulthood, and that several risk factors are tracking from childhood to adult life [3].

The prevalence of childhood obesity has been increasing in developed and developing countries [4, 5]. The Middle East has the highest dietary energy surplus of the developing countries, and the prevalence of NCD risk factors especially obesity is

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rapidly increasing both in adults [6] and children of this region [7].

Usually for clinical practice and epidemiological studies, child overweight and obesity is assessed by indicators based on weight and height measurements, such as weight-for-height or body mass index (BMI) [8]. However, this index cannot distinguish fat from muscle mass, nor can it represent the fat distribution. This overall obesity index may not be the most appropriate in predicting NCDs [9]. Abdominal or upper body fat carries an increased risk for metabolic complications, and waist circumference (WC) is known as a useful anthropometric measure for abdominal obesity in children of different ethnicities [10–12]. Although in adults, different WC cutoff values are suggested for different populations [13], no international WC and waist-to-hip ratio (WHR) standards exist for children. The studies performed in youths of different ethnicities such as the studies in the US [14], Cyprus [15], Italy [16] and Japan [17] showed that WC is a simpler anthropometric index than the sex- and age-specific BMI percentiles in identifying children with dyslipidemia and or high blood pressure [14, 18]. However, the study performed in Portugal, revealed that measures of central adiposity such as WC significantly correlated with serum lipid levels in obese children and adolescents but not in leaner individuals [19].

WC references for children and adolescents are generated in some Western countries including the United Kingdom [20], the United States [21], Canada [22], Spain [23], Cuba [24], Cyprus [25] and Australia [26]. However, as the growth rate and fat patterning vary widely between different populations [27], these cut-offs cannot be generalized to different ethnic groups. This emphasizes the necessity of developing population-specific percentiles.

Consequently, for the first time in Iran, and to the best of our knowledge in Asia, we provided national reference curves for the waist, hip, and WHR percentiles for children and adolescents. This was performed as part of the baseline survey of a longitudinal project entitled: *"Childhood & Adolescence Surveillance and PreventIon of Adult Non-communicable disease": **CASPIAN*** Study (Caspian is the name of the world's largest lake, located in north Iran).

Methods

The baseline survey of this multicenter project was performed at national level in 2003–04 among 21 111 school students, aged 6–18 years, including 10 858 girls (51.4%) and 10 253 boys (48.6%), living in urban and rural areas of 23 (out of 28) provinces in Iran. The samples were selected as a representative sample of nearly 16 000 000 Iranian school-students (from about 67 000 000 total population of the country) with different ethnicities. The study was conducted as a joint collaboration based on a WHO/EMRO grant and support of the National Ministry of Health (MoH), and Ministry of Education [12, 28].

The project team selected students by multistage random cluster sampling from urban and rural areas of different counties. Schools were stratified according to location (urban/rural), and the socioeconomic character of its uptake area, taking into consideration the proportion of the different types of schools (public/private) to avoid socioeconomic bias. Our team obtained written informed consent from parents and oral assent from students after full explanation of the procedure involved.

We prepared our questionnaires in Farsi language and based on the questionnaires of WHO STEPwise approach to NCDs (Tools veer 9.5) and the WHO Global School-based Student Health Survey (GSHS). The validity of their content was affirmed based on observations by a panel of experts, item analysis and reliability measures were assessed based on a pilot study. A team consisting of expert health care professionals, trained for the survey, carried out the field examinations. The participants filled out the questionnaires under the supervision of trained nurses. All instruments were standardized before the examination, and the balances were zero-calibrated. The nurses recorded age and birth date, and measured height and weight twice to ±0.2 cm and to ±0.2 kg, respectively, with subjects being barefoot and lightly dressed; the averages were recorded. As a measure of obesity, BMI was computed as weight in kilograms divided by the square of height in meters. WC was measured with a non-elastic tape at a point midway between the lower border of the rib cage and the iliac crest at the end of normal expiration, and hip circumference (HiC) was measured at the widest part of the hip at the level of the greater trochanter to the nearest 0.5 cm (WHO, 1998). Then we computed the WHR by dividing WC by HiC.

The Data & Safety Monitoring Board of the project closely supervised the quality control and quality assurance of the survey at national level. The data entry staff entered data for all forms and questionnaires twice and checked for completeness and inconsistencies. Data checking process was conducted at district and then at national level.

Data analysis

Data were analyzed by the SPSS statistical package version 13.0 for Windows (SPSS Inc., Chicago, USA). Smoothed age- and gender-specific percentiles were constructed by LMS Chart Marker software package (version 2.0, 2005, UK) according to the method proposed by Cole and Green [29]. Quantitative data are presented as means [standard deviation (SD)]. In order to compare the mean values of the anthropometric measures in different age groups, the subjects were categorized to three age groups (6–9.99, 10–13.99 and 14–18 years) and by using univariate analysis, the mean values of BMI, WC, HiC and WHR of both genders were compared between the age groups studied, and their living area (urban/rural). Partial correlation was used to examine the correlations between the age-adjusted anthropometric measures. The statistical significance was set at $p < 0.05$.

Results

In this national study, the mean (SD) age of students was 12.2 ± 3.3 years, without significant difference between girls and boys. Overall, 84.6% of them were from urban and 15.4% from rural areas, and 90% were from public and 10% from private schools.

Most of students' fathers worked in private sectors (34.9%) or were employee (31.5%), and most of their mothers (88.9%) were housewives. Most of students' parents were literate. The mean (SD) number of household members including the student studied was 5.63 (1.7).

According to the percentiles of Center for Disease Control and Prevention [30], of subjects studied, 13.9% (8.1% of boys and 5.8% of girls) were underweight, 72.7% (36.6% of boys and 36.1% of girls) were normal weight, 8.82% (4.3% of boys and 4.52% of girls) were overweight and 4.5% (2.5% of boys and 2% of girls) were obese.

Table 1 presents the mean (SD) of anthropometric measurements by gender and the age groups. Other than BMI, all differences were significant between genders and age groups, with higher values in boys than in girls, except the higher values of HiC in girls of all age groups, as well as Wt, Ht and BMI of girls, aged 10–13.99 years, that were higher than in boys (Table 1).

There was no significant difference between the mean BMI of boys and girls but the mean BMI of boys living in urban areas was significantly higher than those in rural areas (18.4 ± 3.8 vs. $17.8 \pm 3.6\,kg/m^2$, respectively, $P = 0.01$). All anthropometric measures other than the BMI of girls, were higher in urban than in rural areas (data not shown).

Figure. 1 shows the smoothed reference curves of BMI, WC, HiC and WHR for the 5th, 10th, 25th, 50th, 75th, 90th and 95th percentile in both genders. The BMI percentile curves of girls had a sharp increase from 8 to 15 years, and then began to plateau; but among boys, these curves had a persistent increase until the age of 18 years. For girls, the 50th to 95th percentile curves for WC had a sharp increase from 8 to 13 years of age, and began to plateau after this age, whereas for boys, these curves had a persistent and less sharp increase with age, until the age of 18 years. In girls, the 50th to 95th reference curves for HiC had a sharp increase similar to that observed for WC curves, but at a later age, e.g. 11–15 years, and began to plateau after that age. In boys, these curves had a persistent increase with age and ran nearly parallel to the WC percentile curves. The WHR curves of girls decreased with age until 15 years and began to plateau thereafter, while for boys, the 25th to 95th curves for WHR had a plateau pattern, and the 5th and the 10th percentile curves decreased slowly until 15 years of age.

Figure. 2 presents the age- and gender-specific 5th, 50th and 95th percentile curves for WC obtained in the present study in comparison with the British ones [20]. In boys, the 5th and 50th percentile curves were similar in both studies, but the 95th percentile curve of our study was higher than the British curves. For girls, the 5th percentile curves of both studies were similar, but the 50th and 95th percentile curves of our study were higher than the British ones.

As presented in Table 2, all age-adjusted anthropometric measures were significantly correlated, with strongest correlation found between WC and WHR, followed by WC with BMI, and the weakest between BMI and WHR.

TABLE 1

Comparison of the mean (SD) anthropometric measures of participants by age group (2003–04): CASPIAN Study

	Age groups (years)	Wt (kg)	Ht (cm)	BMI (wt/kg^2)	WC (cm)	HiC (cm)	WHR
Boys	6–9.9	27.08 (7.1)	131.6 (9.3)	15.9 (2.8)	56.9 (8.3)	68.81 (9.8)	0.8 (0.006)
	10–13.99	39.7 (11.2)	148.7 (11.8)	17.7 (3.5)	64.1 (10.0)	78.5 (10.7)	0.8 (0.007)
	14–18	57.2 (12.5)	168.3 (10.2)	20.09 (3.6)	70.4 (10.9)	87.2 (12.0)	0.8 (0.007)
Girls	6–9.99	26.8 (7.6)	129.3 (9.6)	15.8 (2.8)	55.7 (7.9)	69.2 (9.1)	0.7 (0.006)
	10–13.99	41.03 (10.7)	149.4 (10.03)	18.1 (3.6)	63.8 (10.3)	80.2 (11.8)	0.7 (0.006)
	14–18	52.5 (9.9)	159.7 (8.1)	20.5 (3.5)	68.8 (8.7)	89.9 (10.1)	0.7 (0.007)

Wt, weight; Ht, height; BMI, body mass index; WC, waist circumference; HiC, hip circumference; WHR, waist-to-hip ratio.
$P < 0.001$ in all comparisons other than the BMI for the difference between each variable by gender.
$P < 0.001$ in all comparisons for the difference between each variable by age group.

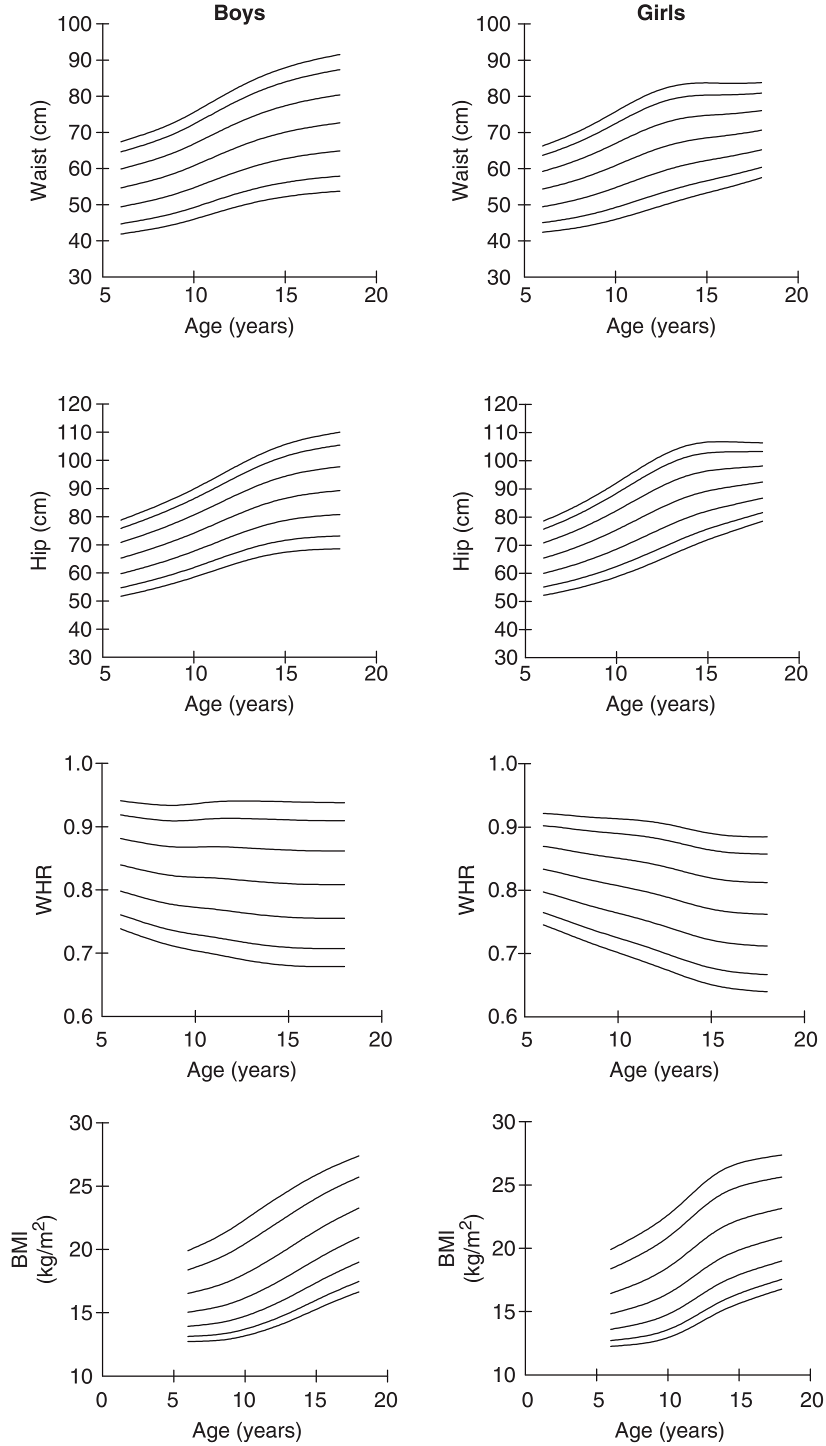

FIG. 1. Age and gender-specfic smoothed reference curves of waist and hip circumferences, waist-to-hip ratio (WHR) and body mass index (BMI) of a national sample ($n = 21\,111$) of Iranian children aged 6–18 years (2003–04): CASPIAN Study.

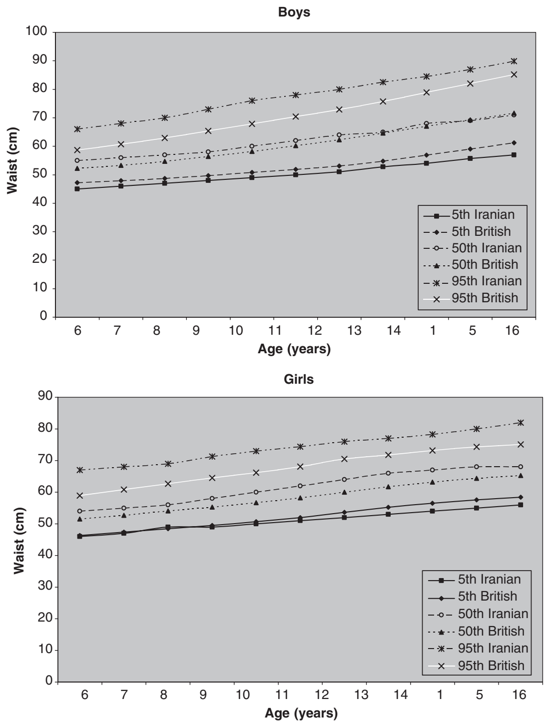

FIG. 2. Age and gender-specific 5th, 50th and 95th Percentile curves of waist circumference of a national sample of Iranian children and adolescents (2003–2004) in comparision with the British percentiles [20]: CASPIAN Study.

TABLE 2

Partial correlation between the age-adjusted anthropometric variables in a national sample (n = 21 111) of Iranian children and adolescents (2003–04): CASPIAN Study

	BMI	WC	HiC	WHR
BMI		$r=0.5$ *	$r=0.4$*	$r=0.1$*
WC	$r=0.5$*		$r=0.7$*	$r=0.4$*
HiC	$r=0.4$*	$r=0.7$*		$r=-0.2$*
WHR	$r=0.1$*	$r=0.4$*	$r=-0.2$*	

*Significant correlation at $P<0.0001$. BMI, body mass index; WC, waist circumference; HiC, hip circumference; WHR, waist-to-hip ratio.

Discussion

In the present national survey, the age- and gender-specific reference curves for WC, HiC and WHR of children and adolescents were constructed for the first time in Iran and, to our knowledge, in Asia. In general, the percentile values of WC and WHR were higher and that of HiC was lower in boys than in girls. In both genders, WC and HiC percentile values increased with age.

For girls, the 50th to 95th percentile curves for WC had a sharp increase from 8 to 13 years and 11 to 15 years, respectively, and began to plateau after this age, whereas for boys, these curves had a persistent and less sharp increase with age, until the age of 18 years. The WHR percentile curves of girls decreased with age until 15 years and began to plateau thereafter, while for boys the 25th to 95th curves for WHR had a plateau pattern.

These findings are comparable with the studies performed in Western countries. In British children of both genders, the mean WC increased with age. The WC percentile curves of girls began to plateau after the age of 13 years while in boys, it continued to rise [20]. The WC percentiles of 11–18-year-old Canadian youth showed a persistent increase with age in both genders, and the WC was higher in boys than in girls [22]. In a study among American adolescents, WC was significantly different among various ethnicities, but in line with the present study, it had a monotonic increase across ages [21]. In Spanish boys, the percentile curves for waist and hip run nearly parallel, while in girls, hip enlarged constantly but waist declined between 11.5 and 14.5 years of age [23]. In a recent study in 7–15-year-old Australian children, in both genders, WC increased with age and boys had higher percentile values [26].

In the present study, the mean WC and WHR were significantly higher in boys, than in girls. Consistent with the study in Spain [23], the mean HiC of girls was significantly higher than in boys, and in both genders, HiC was greater than WC, which is suggested to be because of gender differences in fat deposition during puberty. In addition, in our study, WC was significantly higher in urban than in rural areas, which can be due to the higher prevalence of overweight and the sedentary lifestyle existing in urban areas.

In Spain, WC tended to be higher in boys than in girls, with a significant difference after 11.5 years of age. In general, WC percentiles were higher in boys than in girls especially after 12.5 years of age [23]. In the present study, we found similar differences with a sharp increase in the WC percentile curves of girls between 8 and 13 years of age, while among boys, these curves had a persistent and less sharp increase, and this is suggested to be a reflection of the different timings of the onset of puberty and gender-specific influences on WC.

In Cuban children and adolescents, the WHR percentile changed gradually with age, and was higher in boys than in girls. The WHR graph had three peaks at 6, 11–12 and 15–16 years for Cuban males, and two sharp reductions in 10–13 and 13–16 years of age [24], while in our study, the WHR percentiles of boys had a plateau pattern, while they tended to decline among girls until the age of 15 years.

Comparison of the 50th percentile for WC of British children [20] with those from Spain [23] and Cuba [24] revealed close agreement. The 5th and 50th percentile curves for WC obtained in the current study were similar to British ones [20], but the obtained 95th percentile curve was higher than the British curves. For girls, the obtained 50th and 95th percentile curves were higher than the British ones [20]. It is suggested that the higher percentile values of WC in the current study can be in part due to ethnic differences in body fat patterning and the genetic tendency of Asians to abdominal obesity [2]; in addition current measures are compared with the British data obtained more than 10 years ago, such data have undergone significant changes [31].

Consistent with some previous studies [32], we found significant correlations of BMI with WC and HiC. Studies evaluating childhood obesity according to the definitions based on BMI have shown a rapidly increasing rate in developed and developing countries [33]. Considering the impact of abdominal fat on metabolic disorders, such trends should be assessed according to the measures of abdominal obesity as well. Obtaining information on WC in children and adolescents could be useful as a means of identifying not only the overweight in child population studies, but also the abdominal fat deposition that is found to be related to chronic diseases later in life [32].

The cohort of children in Greece found higher mean BMI than similar American cohorts [34]. In the limited previous studies performed on childhood obesity in Iran, including ours, generalized obesity based on the BMI percentiles, but not abdominal obesity were assessed [35]. Considering the high prevalence of the metabolic syndrome, notably abdominal obesity in Iranian adults and children [36, 37], and considering that the process of this syndrome begins early in life, persists from childhood to adolescence and results in symptomatic diseases in adult life [38], abdominal obesity should be monitored from childhood. Regarding ethnic differences in the pattern of fat deposition and in developing metabolic syndrome, WC percentiles should be generated in different populations until reaching to international percentiles and cut-off values.

It should be noticed that since the prevalence of obesity is increasing over time in most countries, the percentiles of anthropometric measurements are changing as well, and the risk of chronic diseases should not be based on these percentiles. For instance, comparison of cross-sectional studies among British youths showed that WC has increased over the past 10–20 years at a greater rate than BMI [31]. Such data are limited in other countries, and are suggested to be documented in different ethnicities in order to provide the time trends at population level.

Certain factors might have influenced the findings of the present study. One of the limitations of our study is that only children and adolescents attending school are studied, not all of them. However, the magnitude of this factor is estimated to be low, not acting systematically, and may have exerted rather a dilution bias. In addition, for WC measurement, some studies might have used methods different from that used in the present study that makes comparisons difficult. We also wish to acknowledge that our data are compared with the British data obtained more than 10 years ago, that have changed significantly in recent years [31], and these are not necessarily universally accepted cut-offs, but are, nevertheless, useful for comparative purposes in this study.

Conclusion

The reference curves obtained from the present study can provide baseline data for analysis of time trends, as well as for international comparisons. The CASPIAN Study is implementing a surveillance system for NCD-related risk factors and risk behaviors from childhood, and will validate these percentile curves with longitudinal data.

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