BRIEF ARTICLE

Central obesity in Yemeni children: A population based cross-sectional study

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Abstract

AIM: To establish percentile curves and to explore prevalence and correlates of central obesity among Yemeni children in a population based cross-sectional study.

METHODS: A representative sample of 3114 Yemeni children (1564 boys, 1550 girls) aged 6-19 years participating in the HYpertension and Diabetes in Yemen study was studied. Data collection was conducted at home by survey teams composed of two investigators of both genders. Study questionnaire included questions about demographics, lifestyle, and medical history. Anthropometric measurements included body weight, height, waist circumference (WC) and hip circumferences. Waist to hip ratio (WHR) and waist-to-height ratio (WHtR) were then calculated. Age and gender specific smoothed percentiles of WC, WHR, and WHtR were obtained using lambda-mu-sigma parameters (LMS method). The independent predictors of central obesity defined as (1) WC percentile $\geq 90^{th}$; (2) WHtR ≥ 0.5; or (3) WC percentile $\geq 90^{th}$ and WHtR ≥ 0.5, were identified at multivariate logistic regression analysis adjusted for age, gender, urban/rural location, years of school education, sedentary/active life-style.

RESULTS: Percentile curves for WC, WHR and WHtR are presented. Average WC increased with age for both genders. Boys had a higher WC than girls until early adolescence and thereafter girls had higher values than boys. WHR decreased both in boys and girls until early adolescence. Thereafter while in boys it plateaued in girls it continued to decrease. Mean WHtR decreased until early adolescence with no gender related differences and thereafter increased more in girls than in boys towards adult age. Prevalence of central obesity largely varied according to the definition used which was 10.9% for WC $\geq 90^{th}$ percentile, 18.3% for WHtR ≥ 0.5, and 8.6% when fulfilling both criteria. At adjusted logistic regression WC $\geq 90^{th}$ percentiles and WHtR ≥ 0.5 were less prevalent in rural than in urban areas (OR = 0.52, 95%CI: 0.41-0.67 and 0.66, 0.54-0.79 respectively), being more prevalent in children with sedentary lifestyle rather than an active one (1.52, 95%CI: 1.17-1.98 and 1.42, 95%CI: 1.14-1.75, respectively).

CONCLUSION: Yemeni children central obesity indices

percentile curves are presented. Central obesity prevalence varied according to the definition used and was more prevalent in urban sedentary subjects.

Key words: Central obesity; Waist circumference; Waist-to-height ratio; Waist to hip ratio; Developing countries

Core tip: This study presents the first central obesity percentile curves of waist circumference (WC), waist-to-height ratio (WHtR) and waist to hip ratio (WHR) for Yemeni children aged six to nineteen years. WC, WHtR and WHR changed similarly in girls and boys until early adolescence. Thereafter, differently from what observed in Western countries, changes increased more in girls than in boys. Prevalence of central obesity in Yemeni children is low, being associated with urbanization and sedentary lifestyle, and varied according to the definition used: (1) WC percentile $\geq 90^{th}$ (10.9%); (2) WHtR ≥ 0.5 (18.3%); (3) WC percentile $\geq 90^{th}$ and WHtR ≥ 0.5 (8.6%).

INTRODUCTION

Childhood obesity is a matter of growing concern not only in developed but also in developing countries[1]. In the Middle Eastern Crescent (MEC) rates of adolescent overweight and obesity, assessed by the use of body mass index (BMI), are among the highest in the world[2]. The same world area is also characterized by a high prevalence of childhood central obesity as assessed by measuring waist circumference (WC)[3,4]. WC was consistently reported as a more sensitive indicator than BMI of metabolic abnormalities[5], and insulin resistance[6], also at young ages.

Measurements of BMI or WC in children have to be expressed in relation to their sex and age peers, and age and gender specific reference values are required for the diagnosis. Differently from WC, waist to hip ratio (WHR) and BMI a recently proposed index, waist-to-height ratio (WHtR), is only weakly associated with age, and gender[7,8]. Different studies are suggesting a single cut-off value for defining central obesity (WHtR ≥ 0.5)[9]. However, ethnicity and environmental differences might influence body proportions, and it was suggested to use national references to control for variations between populations[10].

Considerable variation in the prevalence of risk factors was reported among different MEC countries[11]

and few information is available in the pediatric population. According to a single study performed in Lahore (Pakistan), 16% of children aged 5-12 years had WHtR above the cut off value of 0.5[12]. HYpertension and Diabetes in Yemen (HYDY) study was thus also designed to provide age- and gender-specific WC, WHR and WHtR smoothed percentiles, and to explore prevalence and correlates of central obesity, among Yemeni children and adolescents aged six to nineteen years.

MATERIALS AND METHODS

Study sites and study population

Target population of the study was the population of the country aged 6-19 years. A representative sample of 3114 Yemeni children (1564 boys, 1550 girls) aged 6 to 19 years (median age 13.5 years) participating in the HYDY survey was studied[13]. The survey used a multi-stage stratified sampling method to select households as the setting for data collection[13]. Briefly in the first stage, Yemen was stratified into three areas, the capital area, the inland, and the coastal area. The governorate of Sana'a (capital area), the governorate of Taizz (inland), and the governorates of Al Hudaydah and Hadramaut (coast) were selected to be representative of the geographic, economic, and climatic characteristics of the three areas. The number of subjects in each area was estimated using the preliminary data provided by the United Nations Population Fund that is the same source used to stratify Yemen population by age and gender[14]. In the second stage, rural and city regions were identified from each study area. In the third stage, districts were arbitrarily identified within each urban and rural region, boundaries being defined using local maps or in consultation with the local health workers. Households were selected because in developing countries not all children in the age groups of interest may have access to school. The survey was completed within 16 mo. The response rate for subjects aged 6-19 years was 96% in urban and 97% in rural locations. The study was approved by the Ethical Committee of the University of Science and Technology, Sana'a, Yemen (Ref. 1-2007). Informed consent was obtained from participants and their parents before data collection. The procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation and with the Helsinki Declaration of 1964, as revised in 2004.

Data collection

Data collection was conducted at home by centrally trained survey teams composed of two investigators of both genders. Children were evaluated between February 2008 and May 2009. Study questionnaire included questions about demographics, lifestyle, and medical history. Anthropometric measurements were taken on standing participants wearing light clothing and without shoes using standard techniques[13]. In the HYDY survey we used a pre-calibrated digital Laica PS6010 scale with a 150 kg capacity (accuracy 100 g) which was frequently checked

Table 1 Descriptive statistics by age group of the 3114 study participants are reported

Age (yr)	n	Weight	Height (cm)	BMI (kg/m^2)	WC	WHtR	HC	WHR
Boys								
6	47	17.4 ± 3.5	104.7 ± 8.4	16.0 ± 3.6	48.6 ± 6.5	0.47 ± 0.06	55.3 ± 9.1	0.88 ± 0.08
7	90	18.8 ± 3.5	109.9 ± 8.8	15.7 ± 2.8	50.8 ± 5.7	0.47 ± 0.07	57.2 ± 6.6	0.89 ± 0.07
8	99	21.3 ± 4.5	114.7 ± 9.4	16.4 ± 3.8	52.2 ± 7.1	0.46 ± 0.07	59.6 ± 7.6	0.88 ± 0.08
9	101	24.3 ± 7.4	120.5 ± 10.6	16.8 ± 4.6	55.6 ± 8.5	0.46 ± 0.08	63.8 ± 8.9	0.87 ± 0.07
10	132	26.8 ± 6.6	126.9 ± 10	16.9 ± 4.1	56.3 ± 7.5	0.45 ± 0.06	64.6 ± 9.1	0.88 ± 0.09
11	102	26.7 ± 4.8	129.3 ± 7.9	16.0 ± 2.8	57.0 ± 7.0	0.44 ± 0.05	65.2 ± 7.5	0.88 ± 0.07
12	157	29.9 ± 7.1	133.6 ± 8.4	16.7 ± 3.5	57.1 ± 8.4	0.43 ± 0.06	67.3 ± 9.0	0.85 ± 0.07
13	116	34.7 ± 8.2	141.5 ± 9.9	17.2 ± 3.4	61.4 ± 8.2	0.43 ± 0.05	71.7 ± 9.1	0.86 ± 0.07
14	158	39.2 ± 8.5	148.1 ± 9.7	17.8 ± 2.9	62.6 ± 8.1	0.42 ± 0.05	73.3 ± 8.5	0.86 ± 0.07
15	112	43.2 ± 11.7	150.3 ± 12.8	18.9 ± 4.0	66.8 ± 9.5	0.45 ± 0.06	77.2 ± 10.2	0.87 ± 0.08
16	100	47.3 ± 8.9	155.2 ± 9.6	19.7 ± 3.9	67.9 ± 9.2	0.44 ± 0.06	79.9 ± 9.3	0.85 ± 0.10
17	119	50.1 ± 9.3	160.1 ± 10.6	19.7 ± 3.9	68.1 ± 9.4	0.43 ± 0.06	80.3 ± 9.7	0.85 ± 0.08
18	133	51.4 ± 9.2	160.0 ± 11.1	20.1 ± 3.2	67.9 ± 8.7	0.43 ± 0.05	80.3 ± 9.1	0.85 ± 0.10
19	98	53.8 ± 11.3	161.3 ± 11.2	20.7 ± 4.0	70.3 ± 11.9	0.44 ± 0.07	82.8 ± 12.2	0.85 ± 0.08
Girls								
6	51	17.8 ± 2.8	104.5 ± 10.5	17.0 ± 3.8	48.7 ± 7.9	0.47 ± 0.07	56.6 ± 10.7	0.87 ± 0.10
7	79	18.2 ± 4.0	109.4 ± 10.0	15.6 ± 3.9	49.8 ± 6.3	0.46 ± 0.07	57.2 ± 7.8	0.88 ± 0.09
8	86	23.2 ± 7.2	115.4 ± 11.4	17.6 ± 5.2	51.7 ± 9.7	0.45 ± 0.08	59.2 ± 9.4	0.87 ± 0.09
9	122	23.5 ± 5.3	118.6 ± 10.7	17.1 ± 4.6	52.3 ± 8.8	0.44 ± 0.09	60.6 ± 10.4	0.87 ± 0.09
10	164	25.8 ± 6.4	122.7 ± 10.3	17.1 ± 3.8	54.9 ± 8.3	0.45 ± 0.07	64.1 ± 10.1	0.86 ± 0.07
11	123	29.2 ± 7.5	130.9 ± 9.9	17.2 ± 4.5	56.6 ± 8.7	0.43 ± 0.07	66.2 ± 10.4	0.86 ± 0.10
12	124	32.5 ± 7.3	133.6 ± 10	18.2 ± 3.6	59.0 ± 9.9	0.44 ± 0.06	69.7 ± 11.4	0.85 ± 0.08
13	133	35.6 ± 6.7	138.2 ± 9.9	18.7 ± 3.6	59.3 ± 10.0	0.43 ± 0.07	70.3 ± 11.6	0.85 ± 0.07
14	130	41.1 ± 7.3	143.9 ± 8.7	19.9 ± 3.3	63.7 ± 9.3	0.44 ± 0.06	75.2 ± 11.1	0.86 ± 0.10
15	102	44.6 ± 10.3	147.9 ± 10.1	20.3 ± 3.9	67.8 ± 8.8	0.46 ± 0.05	80.8 ± 10.3	0.84 ± 0.08
16	108	47.6 ± 9.4	149.9 ± 8.1	21.1 ± 3.5	68.0 ± 9.5	0.45 ± 0.06	82.4 ± 10.2	0.83 ± 0.10
17	97	46.1 ± 8.7	151.4 ± 9.6	20.0 ± 3.1	68.1 ± 9.6	0.45 ± 0.06	82.3 ± 9.9	0.83 ± 0.08
18	128	48.9 ± 8.9	150.5 ± 8.2	21.6 ± 3.6	70.2 ± 9.2	0.47 ± 0.06	84.3 ± 9.8	0.84 ± 0.09
19	105	50.9 ± 10.3	152.2 ± 7.9	21.9 ± 4.0	70.2 ± 11.9	0.46 ± 0.07	86.1 ± 11.5	0.82 ± 0.09

Sample sizes, mean ± SD for weight, height, body mass index (BMI), waist circumference (WC), waist-to-height ratio (WHtR), hip circumference (HC), and waist to hip ratio (WHR) for Yemeni boys and girls six to nineteen years of age (*n* = 3114).

by a known-weighing object. The CV for inter- and intra-observer effects for most anthropometric measures was < 5%. Height was measured to the nearest 0.5 cm using a stadiometer. WC was measured with a non-elastic tape positioned at a point midway between the lower border of the rib cage and the top of the iliac crest, and hip circumference (HC) was measured at the widest part of the hip at the level of the greater trochanter. WC and HC were measured to the nearest 0.5 cm and WHR and WHtR were then calculated.

BMI was computed as the weight in kilograms divided by the square of the height in meters. Central obesity was evaluated by analyzing WHtR ⩾ 0.5, WC ⩾ 90th percentile and the combination of both WHtR ⩾ 0.5 and WC ⩾ 90th percentile. Overweight and obesity were also defined as having a BMI above the age and sex-specific thresholds of the international obesity task force (IOTF) respectively the equivalent of BMI > 25 kg/m^2 and the equivalent of BMI > 30 kg/m$^{2[15]}$.

Statistical analysis

Description and validation of the database can be found elsewhere[16]. Data were preliminary checked for outliers using a cut-off of ± 5 SD of the corresponding age and sex Z-scores[17]. Smoothed age (by year) and gender-specific percentiles (3rd, 5th, 10th, 25th, 50th, 75th, 90th, 95th, and 97th) for WC, WHR and WHtR were then constructed by means of a comprehensive method of smoothing for growth curves using lambda-mu-sigma parameters according to Cole (LMS method)[18,19].

The LMS method summarizes the growth reference curve with three curves representing the median (M), the coefficient of variation (S) and the power to remove skewness from the data (L) by age and was implemented in the Generalized Additive Model for Location, Scale and Shape (GAMLSS) package included in R 2.14.0 software for Windows. In LMS method, GAMLSS parameters and the parameters of Box-Cox power exponential distribution were used for model fitting to data. These reference curves were fitted on the original data and the best fit was used to construct smoothed percentile curves. After the application of the BoxCox power transformation the data at each age were normally distributed and the points on each centile curve were defined in terms of the formula: $M = (1 + LSz)^{1/L}$ where L, M, and S are values of the fitted curves at each age, and z indicates the z score for the required centile.

WC, WHR, and WHtR differences between genders were tested within age groups using Mann-Whitney *U*-test. Data are expressed as crude values. Comparisons

Age (yr)	*n*	3rd	5th	10th	25th	50th	75th	90th	95th	97th
Boys										
6	47	36.60	38.50	41.30	45.40	48.90	52.50	57.20	60.70	63.30
7	90	37.60	39.70	42.60	46.80	50.40	54.10	58.90	62.50	65.20
8	99	38.80	40.90	43.90	48.20	52.00	55.80	60.80	64.50	67.30
9	101	40.00	42.20	45.30	49.80	53.60	57.60	62.70	66.50	69.40
10	132	41.20	43.40	46.60	51.20	55.10	59.20	64.40	68.40	71.30
11	102	42.20	44.50	47.70	52.50	56.50	60.70	66.10	70.10	73.10
12	157	43.40	45.80	49.10	54.00	58.10	62.40	68.00	72.10	75.20
13	116	44.90	47.40	50.80	55.80	60.10	64.60	70.30	74.70	77.90
14	158	46.70	49.20	52.80	58.00	62.40	67.10	73.00	77.50	80.80
15	112	48.40	51.00	54.70	60.10	64.70	69.50	75.70	80.30	83.80
16	100	49.70	52.40	56.30	61.80	66.60	71.50	77.80	82.60	86.20
17	119	50.80	53.50	57.40	63.10	67.90	73.00	79.40	84.30	87.90
18	133	51.60	54.30	58.30	64.10	69.00	74.10	80.70	85.60	89.30
19	98	52.30	55.10	59.10	65.00	70.00	75.20	81.80	86.80	90.60
Girls										
6	51	34.30	36.50	39.70	44.40	48.70	53.10	58.00	61.30	63.60
7	79	35.10	37.40	40.60	45.50	49.90	54.30	59.30	62.70	65.10
8	86	36.00	38.30	41.70	46.60	51.10	55.70	60.80	64.30	66.80
9	121	37.10	39.40	42.90	48.00	52.60	57.30	62.60	66.20	68.70
10	164	38.40	40.80	44.40	49.60	54.50	59.30	64.70	68.50	71.10
11	123	39.80	42.40	46.10	51.50	56.50	61.60	67.20	71.10	73.80
12	124	41.40	44.00	47.90	53.50	58.70	64.00	69.80	73.90	76.70
13	132	43.00	45.70	49.70	55.60	61.00	66.50	72.60	76.70	79.70
14	130	44.70	47.50	51.70	57.80	63.40	69.10	75.40	79.80	82.80
15	102	46.20	49.20	53.50	59.80	65.60	71.50	78.00	82.50	85.70
16	108	47.40	50.50	54.90	61.40	67.30	73.40	80.10	84.70	87.90
17	97	48.40	51.50	55.90	62.60	68.70	74.80	81.60	86.30	89.60
18	128	49.10	52.30	56.90	63.60	69.80	76.00	83.00	87.70	91.10
19	105	49.80	53.00	57.60	64.50	70.70	77.10	84.10	88.90	92.30

Table 2 Age, and gender specific smoothed waist circumference percentiles for Yemeni children and adolescents aged 6 to 19 years (cm)

Age, and gender specific smoothed waist circumference percentiles for Yemeni children and adolescents aged 6- 19 years (*n* = 3114).

were performed by using logistic regression with adjustment for confounding variables including age (years), gender, years of school education, urban/rural residency and sedentary/active lifestyle. Results are expressed as adjusted odd ratio (OR) with 95% confidence interval (CI). Test of hypothesis was done at significance level 0.05 two sided. SPSS software, version 19.0 (SPSS Inc., Chicago., IL, United States) was used for statistical comparisons.

RESULTS

Descriptive statistics for weight, height, BMI, WC, WHtR, HC, and WHR by age group of the 3114 study participants are reported in Table 1. Age and gender specific WC, WHR and WHtR smoothed percentiles are presented in Tables 2-4 respectively. Mean BMI increased with age in both genders. However, girls aged 11 years or more had BMI values higher than boys (19.8 kg/m^2, 95%CI: 19.6-20.0 and 18.4 kg/m^2, 95%CI: 18.2-18.7 for girls and boys respectively). Overall 13.9% of participants (females 15.8%; 95%CI: 14.0-17.6; males 12.1%; 95%CI: 10.5 to 13.7) were overweight according to the IOTF criteria, 5.0% being obese (females 5.7%; 95%CI: 4.6-6.9; males 4.2%; 95%CI: 3.2-5.2).

WC increased with age among both boys and girls (Table 1). Boys had a non-significantly higher WC than girls until early adolescence (54.1 ± 7.7 cm *vs* 53.1 ± 8.7 cm, *P* = 0.09 respectively for subjects aged ≤ 11 years). Thereafter girls had higher WC values than boys (65.5 ± 10.7 cm *vs* 64.8 ± 10.0 cm, *P* < 0.05 respectively for subjects aged > 11 years). Girls had lower 50th and 90th WC than boys in younger ages (6-11 years), but higher in older ages (12-19 years) (Table 2) (Figure 1A and D).

Mean WHR decreased with age among both boys and girls until early adolescence. Thereafter values plateaued in boys whereas in girls it continued to decrease. Boys had a higher WHR than girls in early adolescence (0.88 ± 0.08 *vs* 0.87 ± 0.09, *P* < 0.01 respectively for subjects aged ≤ 11 years) as well as thereafter (0.85 ± 0.08 *vs* 0.84 ± 0.09, *P* < 0.01 respectively for subjects aged > 11 years). Girls always had lower 50th and 90th WHR than boys (Table 3) (Figure 1B and E).

Mean WHtR was slightly higher among boys than girls for subjects aged ≤ 11 years (0.455 ± 0.067 and 0.448 ± 0.075 respectively, *P* = 0.07). Thereafter WHtR values were higher in girls (0.450 ± 0.063) than in boys (0.431 ± 0.059, *P* < 0.01). WHtR 50th percentile in both sexes decreased from the age of 6 years reaching the minimum at the age of 13 years, increasing thereafter mainly in girls. Girls had higher 50th and 90th WHtR percentiles than boys between the age of 14-19 years (*P* < 0.05) (Table 4) (Figure 1C and F).

Table 3 Age, and gender specific smoothed waist hip ratio percentiles for Yemeni children and adolescents aged 6 to 19 years

Age (yr)	n	3th	5th	10th	25th	50th	75th	90th	95th	97th
Boys										
6	47	0.73	0.76	0.79	0.84	0.89	0.93	0.99	1.03	1.05
7	90	0.73	0.75	0.79	0.84	0.88	0.93	0.98	1.02	1.04
8	99	0.72	0.75	0.78	0.83	0.88	0.92	0.97	1.01	1.04
9	101	0.72	0.74	0.78	0.83	0.87	0.92	0.97	1.01	1.03
10	132	0.72	0.74	0.77	0.82	0.86	0.91	0.96	1.00	1.03
11	102	0.71	0.73	0.77	0.82	0.86	0.90	0.96	0.99	1.02
12	157	0.71	0.73	0.76	0.81	0.85	0.90	0.95	0.99	1.01
13	116	0.70	0.73	0.76	0.81	0.85	0.90	0.95	0.98	1.01
14	158	0.70	0.73	0.76	0.81	0.85	0.89	0.95	0.98	1.01
15	112	0.70	0.73	0.76	0.81	0.85	0.89	0.95	0.98	1.01
16	100	0.70	0.72	0.76	0.80	0.85	0.89	0.94	0.98	1.01
17	119	0.70	0.72	0.76	0.80	0.85	0.89	0.94	0.98	1.00
18	133	0.70	0.72	0.76	0.80	0.85	0.89	0.94	0.98	1.00
19	98	0.70	0.73	0.76	0.81	0.85	0.90	0.95	0.98	1.01
Girls										
6	51	0.70	0.73	0.77	0.82	0.87	0.93	0.98	1.01	1.04
7	79	0.70	0.73	0.76	0.82	0.87	0.92	0.98	1.01	1.03
8	86	0.70	0.72	0.76	0.81	0.87	0.92	0.97	1.00	1.03
9	121	0.69	0.72	0.75	0.81	0.86	0.91	0.96	1.00	1.02
10	164	0.69	0.71	0.75	0.80	0.86	0.91	0.96	0.99	1.02
11	123	0.68	0.71	0.75	0.80	0.85	0.90	0.95	0.99	1.01
12	124	0.68	0.71	0.74	0.80	0.85	0.90	0.95	0.98	1.01
13	132	0.68	0.70	0.74	0.79	0.84	0.90	0.95	0.98	1.00
14	130	0.68	0.70	0.74	0.79	0.84	0.89	0.94	0.98	1.00
15	102	0.67	0.70	0.73	0.79	0.84	0.89	0.94	0.97	0.99
16	108	0.67	0.69	0.73	0.78	0.83	0.88	0.93	0.97	0.99
17	97	0.67	0.69	0.73	0.78	0.83	0.88	0.93	0.96	0.98
18	128	0.66	0.69	0.72	0.78	0.83	0.88	0.93	0.96	0.98
19	105	0.66	0.68	0.72	0.77	0.82	0.87	0.92	0.95	0.97

Age, and gender specific smoothed waist hip ratio percentiles for Yemeni children and adolescents aged 6-19 years (*n* = 3114).
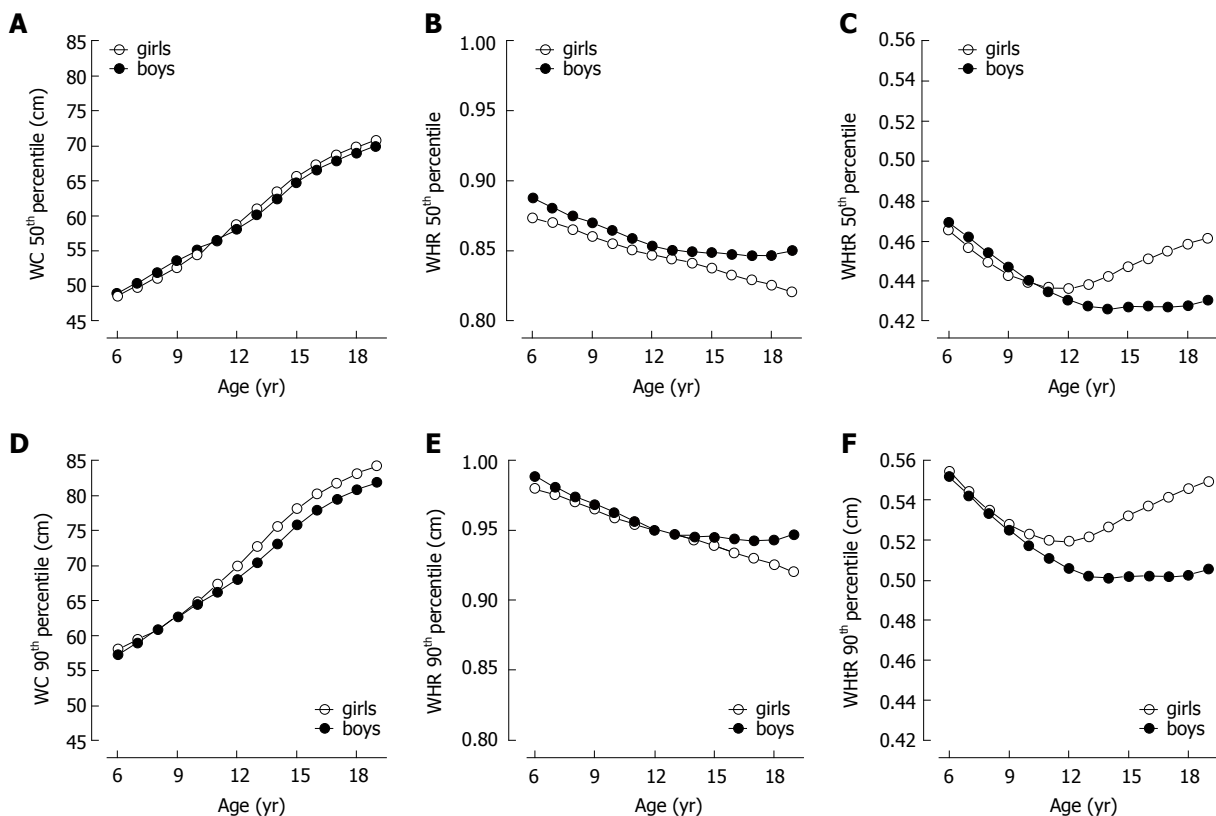
Figure 1 50th and 90th percentile curves. Waist circumference (WC, A and D), waist to hip ratio (WHR, B and E), and waist to height ratio (WHtR, C and F) for Yemeni boys (filled circles) and girls (empty circles).

Table 4 Age, and gender specific smoothed waist-to-height ratio percentiles for Yemeni children and adolescents aged 6 to 19 years

Age (yr)	n	3rd	5th	10th	25th	50th	75th	90th	95th	97th
Boys										
6	47	0.35	0.37	0.4	0.44	0.47	0.51	0.55	0.59	0.61
7	90	0.35	0.36	0.39	0.43	0.46	0.50	0.54	0.58	0.60
8	99	0.34	0.36	0.38	0.42	0.45	0.49	0.53	0.57	0.59
9	101	0.34	0.35	0.38	0.41	0.45	0.48	0.53	0.56	0.58
10	132	0.33	0.35	0.37	0.41	0.44	0.47	0.52	0.55	0.57
11	102	0.33	0.34	0.37	0.40	0.44	0.47	0.51	0.54	0.57
12	157	0.32	0.34	0.36	0.40	0.43	0.46	0.51	0.54	0.56
13	116	0.32	0.34	0.36	0.40	0.43	0.46	0.50	0.53	0.56
14	158	0.32	0.34	0.36	0.40	0.43	0.46	0.50	0.53	0.55
15	112	0.32	0.34	0.36	0.40	0.43	0.46	0.50	0.53	0.56
16	100	0.32	0.34	0.36	0.40	0.43	0.46	0.50	0.53	0.56
17	119	0.32	0.34	0.36	0.40	0.43	0.46	0.50	0.53	0.56
18	133	0.32	0.34	0.36	0.40	0.43	0.46	0.50	0.53	0.56
19	98	0.32	0.34	0.36	0.40	0.43	0.46	0.51	0.54	0.56
Girls										
6	51	0.34	0.36	0.38	0.43	0.47	0.51	0.55	0.59	0.61
7	79	0.33	0.35	0.38	0.42	0.46	0.50	0.54	0.58	0.60
8	86	0.32	0.34	0.37	0.41	0.45	0.49	0.53	0.57	0.59
9	121	0.32	0.34	0.36	0.41	0.44	0.48	0.53	0.56	0.58
10	164	0.32	0.34	0.36	0.40	0.44	0.48	0.52	0.55	0.58
11	123	0.32	0.33	0.36	0.40	0.44	0.48	0.52	0.55	0.57
12	124	0.32	0.33	0.36	0.40	0.44	0.48	0.52	0.55	0.57
13	132	0.32	0.33	0.36	0.40	0.44	0.48	0.52	0.55	0.57
14	130	0.32	0.34	0.36	0.40	0.44	0.48	0.53	0.56	0.58
15	102	0.32	0.34	0.37	0.41	0.45	0.49	0.53	0.56	0.59
16	108	0.33	0.34	0.37	0.41	0.45	0.49	0.54	0.57	0.59
17	97	0.33	0.35	0.37	0.42	0.45	0.50	0.54	0.57	0.60
18	128	0.33	0.35	0.38	0.42	0.46	0.50	0.55	0.58	0.60
19	105	0.33	0.35	0.38	0.42	0.46	0.50	0.55	0.58	0.60

Age, and gender specific smoothed waist-to-height ratio percentiles for Yemeni children and adolescents aged 6-19 years (*n* = 3114).

Table 5 Logistic regression of factors associated to different definitions of central obesity

Variables	WHtR ≥ 0.5 OR (95%CI)	WC ≥ 90th OR (95%CI)	WHtR ≥ 0.5/WC ≥ 90th OR (95%CI)
Age (yr)	0.98 (0.94-1.02)	0.95 (0.90-1.00)	0.96 (0.90-1.01)
Gender (girls *vs* boys)	1.55 (1.29-1.89)	0.97 (0.77-1.22)	1.22 (0.94-1.57)
Location (rural *vs* urban)	0.66 (0.54-0.79)	0.52 (0.41-0.66)	0.52 (0.40-0.67)
Education (yr)	0.99 (0.95-1.03)	1.08 (1.02-1.14)	1.05 (0.99-1.11)
Sedentary (*vs* active)	1.42 (1.14-1.75)	1.52 (1.17-1.98)	1.65 (1.24-2.19)

Logistic regression of factors associated to different definitions of central obesity: waist-to-height ratio (WHtR) ≥ 0.5, waist circumference (WC) ≥ 90th percentile, and the combination of WHtR ≥ 0.5, and WC ≥ 90th percentile. Data are reported as adjusted odd ratio (OR) with 95%CI.

Prevalence of subjects with WC ≥ 90th percentile, WHtR greater than 0.5, and of those fulfilling both criteria were 10.9%, 18.3%, and 8.6% in the overall population. More precisely 10.8% of girls (95%CI: 9.2-12.3), 11.0% of boys (95%CI: 9.4-12.5) had WC ≥ 90th percentile; 21.7% of girls (95%CI: 19.6-23.7), 14.9% of boys (95%CI: 13.1-16.6) had WHtR ≥ 0.5; 9.5% of girls (8.0-11.0), 7.8% of boys (95%CI: 6.4-9.1) had both WC ≥ 90th percentile and WHtR ≥ 0.5. Characteristics more frequently associated with reported criteria for central obesity were investigated at multivariate logistic regression, main results being reported in Table 5. In particular WC ≥ 90th percentiles and WHtR ≥ 0.5 were less prevalent in rural than in urban areas (OR = 0.52, 95%CI: 0.41-0.67 and 0.66, 0.54-0.79 respectively), being more prevalent in children with sedentary lifestyle (OR = 1.52, 95%CI: 1.17-1.98 and 1.42, 1.14-1.75 respectively). Differences by gender were evident only when considering a cut-off which is independent from the Yemeni population (WHtR ≥ 0.5). A minor association was observed between years of school education and WC ≥ 90th.

DISCUSSION

This study, to our knowledge provides the first gender- and age-specific WC, WHR and WHtR percentiles for Yemeni children 6 to 19 years of age. As observed in other studies WC increases with age, boys having higher WC

Table 6 Comparison between waist-to-height ratio 10th, 50th and 90th percentiles for Yemeni, Pakistani (*n* = 12), and Norwegian (*n* = 22) boys and girls
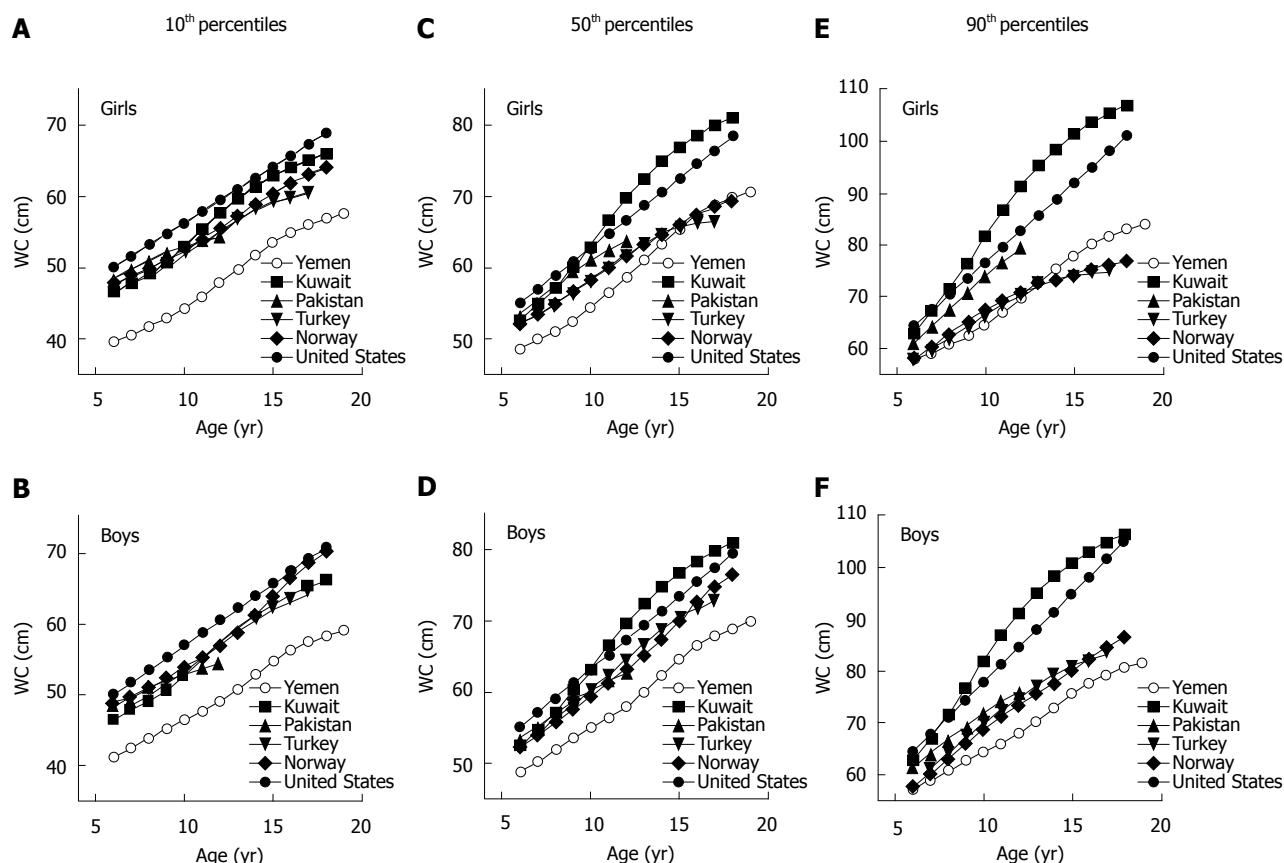
Age	10th percentiles			50th percentiles			90th percentiles		
	Y	P	N	Y	P	N	Y	P	N
Boys									
6	0.4	0.41	0.41	0.47	0.46	0.45	0.55	0.52	0.49
7	0.39	0.4	0.4	0.46	0.45	0.44	0.54	0.52	0.48
8	0.38	0.4	0.39	0.45	0.45	0.43	0.53	0.52	0.48
9	0.38	0.39	0.38	0.45	0.45	0.42	0.53	0.52	0.48
10	0.37	0.39	0.38	0.44	0.44	0.42	0.52	0.52	0.48
11	0.37	0.38	0.37	0.44	0.44	0.42	0.51	0.52	0.48
12	0.36	0.38	0.37	0.43	0.44	0.41	0.51	0.52	0.47
13	0.36	-	0.36	0.43	-	0.41	0.5	-	0.47
14	0.36	-	0.36	0.43	-	0.41	0.5	-	0.46
15	0.36	-	0.37	0.43	-	0.41	0.5	-	0.46
16	0.36	-	0.37	0.43	-	0.41	0.5	-	0.47
17	0.36	-	0.38	0.43	-	0.42	0.5	-	0.47
18	0.36	-	0.38	0.43	-	0.43	0.5	-	0.48
19	0.36	-	-	0.43	-	-	0.51	-	-
Girls									
6	0.38	0.41	0.42	0.47	0.45	0.45	0.55	0.51	0.49
7	0.38	0.4	0.4	0.46	0.45	0.43	0.54	0.52	0.49
8	0.37	0.4	0.4	0.45	0.45	0.43	0.53	0.52	0.48
9	0.36	0.4	0.39	0.44	0.45	0.42	0.53	0.53	0.48
10	0.36	0.39	0.39	0.44	0.44	0.41	0.52	0.53	0.47
11	0.36	0.38	0.38	0.44	0.44	0.41	0.52	0.53	0.46
12	0.36	0.37	0.38	0.44	0.43	0.4	0.52	0.52	0.46
13	0.36	-	0.37	0.44	-	0.4	0.52	-	0.45
14	0.36	-	0.37	0.44	-	0.4	0.53	-	0.45
15	0.37	-	0.37	0.45	-	0.4	0.53	-	0.45
16	0.37	-	0.38	0.45	-	0.4	0.54	-	0.45
17	0.37	-	0.38	0.45	-	0.41	0.54	-	0.46
18	0.38	-	0.39	0.46	-	0.42	0.55	-	0.47
19	0.38	-	-	0.46	-	-	0.55	-	-

Comparison between waist-to-height ratio 10th, 50th and 90th percentiles for Yemeni (Y), Pakistani (P), and Norwegian (N) boys and girls.

than girls at childhood[3,4,12,20-24]. In Yemen central obesity is more prevalent in adult women than in men[13] and, according to the present findings, this difference originates at early adolescence when WC starts to be higher in girls than in boys. A WC level of action of 80 cm has been proposed for adult women[25]. The 90th percentile of WC in Yemeni girls crosses this limit already at the age of 16 years. Conversely boys never reach the WC level of action of 94 cm proposed for adult men[25]. According to the present findings the prevalence of central obesity (WC ≥ 90th percentile, or WHtR ≥ 0.5, or both WHtR ≥ 0.5 and WC ≥ 90th percentile) was higher in urban than in rural settings, and in subjects with sedentary than active lifestyle. Years of school education, which can be considered an index of census, was predictor of having a WC ≥ 90th. Cut off values of WC have to be based on percentiles to compensate for variation in child development. WHtR was more recently proposed to overcome this limit and to offer the simplest cut-off value for screening central obesity in the clinical practice: "keep your WC to less than half your height"[9]. Also when considering WHtR, the prevalence of central obesity in Yemen was higher among girls than boys, differences being evident after early adolescence. Similarly after early

adolescence WHR in boys had a plateau while in girls it continued to decrease. The clear identification of a high risk subgroup is important. According to the present survey girls at early adolescence, living in urban areas, educated, with sedentary lifestyle have to be considered as a target for future educational programs aimed at limiting central obesity in Yemeni adult women. Furthermore central obesity in children was reported to be an independent predictor of insulin resistance, lipid levels, and high blood pressure[6,26]. As suggested by the international diabetes foundation[27] outcome studies investigating future metabolic syndrome, diabetes and cardiovascular disease in developing countries are required.

During the last decades, age and sex-specific WC percentiles have been obtained in different western, and MEC countries. In Yemen early adolescence is the starting point for the increase of the 90th percentile of WC in girls differently from what observed in Norway[23] where at this age the same increase was reported to occur in boys (Figure 2). A low physical activity for girls living in Yemen might be considered. This age related change was however not reported in Turkish girls[21]. The differences among females in Yemen may be related to other factors such as weather, absence of sidewalks and parks, and cul-

Figure 2 Comparison of waist circumference 10th, 50th, and 90th percentile curve. Waist circumference (WC) 10th, 50th, and 90th percentile curves for Yemeni, Kuwaiti[3], Pakistani[12], Turkish[20], United States[21], and Norwegian[22] girls (A, C, E) and boys (B, D, F).

ture such as attitudes of males towards women walking for leisure. Other cultural aspects, such as the adoption of western aesthetic values modifying the traditional consideration of plumpness as an index of beauty might also play a role[28]. In Kuwait[3] early adolescence is the starting point for central obesity both in girls and in boys probably because of the high income of the country (Figure 2). Comparison with data obtained in United States[22] might be more complex due to the composite ethnicity of participants.

When considering WHtR data from different countries, the average height in the country has to be considered. In Yemen the 90th percentile values were comparable to those found in Pakistan[12] although significantly higher than those found in Norway[23] (Table 6). More precisely, when considering this index in developing countries the possible contribution of malnutrition on height should be taken into account. According to the present findings more than 50% of Yemeni girls and boys aged 6 to 18 years have WC values below those of the United States 10th percentiles[22] (Figure 2). Even when considering subjects living in the MEC, more than 25% of Yemeni children have WC values below those of the 10th percentiles measured in Kuwait[3] and Pakistan[12] (Figure 2).

There are limitations and strengths in this study. A first limitation is the unequal number of subjects in the

28 age strata. The population sample in the HYDY study was stratified by decades of age rather than by years of age. However discrepancy between age groups is limited and the less numerous group included an acceptable number of subjects. Secondly, the Tanner stage was not assessed. A third limitation is that in the HYDY study biochemical investigations on blood (glucose, cholesterol, and triglycerides) were not assessed in subjects aged less than 14 years. This decision, which precluded us drawing conclusions about the associations with obesity indices, was taken considering the child's perceptions and fears of the procedure of blood collection. The strengths of our study are (1) the novelty in Yemeni children; (2) the large sample size of children studied over different areas of the country with a constantly reproducible study procedure; and finally (3) the door to door approach adopted in the sampling procedure. We decided to adopt a door-to-door procedure rather than performing a school-based study because in low income countries not all children may have access to school. Considering the very high response rate we can exclude the presence of relevant selection bias. Our data provide the first description of the percentile distribution, derived from a large nationally representative sample of 6-19 year old children, of WC, WHR and WHtR in urban and rural Yemeni population.

In conclusion, HYDY data show a large discrepancy of central obesity prevalence among Yemeni children

probably because the country is still in an early stage of the nutritional transition and there are population segments which are affected by malnutrition[29]. Prevalence of central obesity in Yemeni children is low, being associated with urbanization and sedentary lifestyle. WC, WHtR and WHR changed similarly in girls and boys until early adolescence. Thereafter, differently from what observed in Western countries, WC, WHtR and WHR changes increased more in girls than in boys. The importance of changes observed at early adolescence among girls living in urban areas, might be relevant for future National programs aimed at promoting physical activity and control of central obesity in women.

ACKNOWLEDGMENTS

COMMENTS

Background

Children obesity also in the Middle Crescent Area is a matter of growing concern. Childhood central obesity is assessed by measuring waist circumference (WC). However, ethnicity and environmental differences might influence body proportions, and the usefulness of national references to control for variations between populations was suggested.

Research frontiers

In children WC has to be expressed relatively to their sex and age peers. Differently from WC and waist to hip ratio (WHR) a recently proposed index, waist-to-height ratio (WHtR), is only weakly associated with age and gender, and different studies are suggesting a single cut-off value for defining central obesity (WHtR $\geqslant$ 0.5).

Innovations and breakthroughs

Prevalence of central obesity in Yemeni children is low, being associated with urbanization and sedentary lifestyle. WC, WHtR and WHR changed similarly in girls and boys until early adolescence. Thereafter, differently from what observed in Western countries, WC, WHtR and WHR changes increased more in girls than in boys.

Applications

The importance of the changes observed at early adolescence among sedentary girls living in urban areas, might be relevant for future National program aimed at promoting physical activity and control of central obesity in women.

Terminology

Central obesity measures the abdominal obesity using parameters such as WC, WHR and WHtR, and seems to be better correlated with cardiovascular disease and mortality than general obesity measured using the body mass index.

Peer review

The authors provided the first central obesity percentile curves of WC, WHtR and WHR for Yemeni children aged six to nineteen years. As expected the prevalence of central obesity in Yemeni children is low, being associated with urbanization and sedentary lifestyle. The study showed also that WC, WHtR and WHR values changed similarly in girls and boys until early adolescence. However, thereafter, differently from what observed in Western countries, these changes increased more in girls than in boys indicating that this is a crucial moment in the arising of adult women central obesity.

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