

# Waist circumference percentiles of black South African children aged 10 - 14 years from different study sites

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**Background.** Waist circumference (WC) is a useful predictor of cardiometabolic risk in children. Published data on WC percentiles of children from African countries are limited.

**Objectives.** To describe age- and sex-specific WC percentiles in black South African (SA) children from different study sites, and compare these percentiles with median WC percentiles of African-American (AA) children.

**Methods.** Secondary data on WC for 10 - 14-year-old black SA children (N=4 954; 2 406 boys and 2 548 girls) were extracted from the data sets of six studies. Smoothed WC percentile curves for boys and girls were constructed using the LMS method. The 50th percentile for age- and sex-specific WC measurements was compared across study sites and with AA counterparts.

**Results.** Girls had higher WC values than boys from the 50th to 95th percentiles at all ages. The 50th WC percentiles of all groups of SA children combined were lower than those of AA children. When SA groups were considered separately, Western Cape children had median WC values similar to AA children, while rural Limpopo children had the lowest WC values. The 95th percentiles for Western Cape girls exceeded the adult cutoff point for metabolic syndrome (WC ≥80 cm) from age 11 years.

**Conclusions.** The differences in WC values for 10 - 14-year-old children across the six study sites highlight the need for nationally representative data to develop age-, sex- and ethnic-specific WC percentiles for black SA children. The results raise concerns about high WC among Western Cape girls.

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Obesity and related metabolic disease risk are global public health concerns, not only among adults but also in children and adolescents.<sup>[1]</sup> Evidence shows that the prevalence of obesity and metabolic syndrome is increasing among children and adolescents worldwide,<sup>[2]</sup> and this has important public health implications.<sup>[3]</sup> Childhood obesity has negative health implications in children presenting with associated metabolic and cardiovascular risk factors, and there is therefore a need for early identification of obesity-related disease risk in children for targeted interventions.<sup>[4]</sup>

Waist circumference (WC), a generally acceptable measure of central obesity, gives relevant information about body fat distribution.<sup>[5]</sup> The use of WC as a screening tool to identify children at high risk of cardiometabolic disorders and cardiovascular diseases has been recommended.<sup>[6]</sup> The need to develop WC percentiles and cutoff points for various populations and ethnic groups that are due to differences in body size and composition has been suggested.<sup>[7,8]</sup> Ethnic-specific WC cutoff points associated with increased risk for metabolic and cardiovascular diseases have been defined for adult men and women.<sup>[9]</sup> However, WC reference values for children and adolescents have been defined in only a few countries, for example, the USA,<sup>[10]</sup> Canada,<sup>[11]</sup> Australia,<sup>[12]</sup> Britain,<sup>[13]</sup> Iran<sup>[3]</sup> and Malaysia.<sup>[14]</sup>

These references may not be applicable to children from the African continent, owing to differences in ethnic and racial backgrounds. Comparison of WC data of children and adolescents in Africa is compounded by limited data describing WC percentiles and cutoff points.<sup>[15]</sup> Nationally representative WC data from developing countries is therefore required for children and adolescents. A study reported WC values among Nigerian children and adolescents,<sup>[15]</sup> but did not derive percentile curves.

South Africa (SA), like other middle-income countries undergoing epidemiological nutrition transition, is experiencing an increase in childhood obesity and related metabolic complications. Data on WC cutoff points and percentiles for black SA children are unavailable, and cutoff points for Europids are therefore used in African children. This poses a major challenge for body composition research.<sup>[16,17]</sup> The present study aimed to describe WC percentiles in black SA children from six different studies, and to compare median WC values with those for African American (AA) children and adolescents.

## Methods

### Study design and sample

Secondary data analysis was performed using anthropometric data

for black SA children from six cross-sectional surveys that were done in different provinces of SA (Table 1): (i) the THUSABANA (Transition and Health during Urbanisation of South Africans *Bana* [children]) study in the North West Province among children aged 10 - 15 years old;<sup>[18]</sup> (ii) Ellisras Longitudinal Growth and Health Study in Limpopo Province among children aged 7 - 13 years;<sup>[19]</sup> (iii) a study of body composition in urban children aged 6 - 13 years in Polokwane, Limpopo Province;<sup>[20]</sup> (iv) a study of metabolic syndrome in children aged 10 - 16 years in Cape Town in the Western Cape Province;<sup>[16]</sup> (v) a study of rural children and adolescents aged 1 - 20 years from Mpumalanga Province, selected from the Agincourt database;<sup>[21]</sup> and (vi) a study of primary school children aged 9 - 15 years from four schools in the Valley of a Thousand Hills, a peri-urban area in KwaZulu-Natal Province.

Most children in these studies were from low to middle socioeconomic backgrounds, and aged 6 - 18 years. However, owing to the differences in the age ranges of the studies, only age groups that were common to the majority of the data sets and with sufficient sample sizes (>20 children per sex and age group) were included in the present study (Table 2). Sufficient data from children aged 10 - 14 years were available in all data sets and included in the current analysis ( $N=4\ 954$ ; 2 406 boys and 2 548 girls). In each of the six studies, informed consent had been obtained from parents or

guardians of all children, and the children themselves had assented to participate in the studies. All studies were conducted by academics from SA universities, and the research ethics committees of the respective universities approved the studies.

### Anthropometric measurements

Anthropometric data were extracted from each of the data sets for the six studies, and used for analysis in the present study. Details of measurements are described in full in the different studies.<sup>[16,18-22]</sup> In short, anthropometric measurements of height, weight and waist circumference (WC) were taken following standard procedures.<sup>[23]</sup> Height was measured to the nearest 0.1 cm on a free-standing stadiometer fitted with a head board. The subject stood barefoot on the base of the stadiometer, wearing light clothing, with heels together, head positioned such that the line of vision is perpendicular to the body (Frankfort plane) and arms hanging freely by the sides. The movable headboard was brought onto the topmost point of the head with sufficient pressure to compress hair, and the reading was taken. Body weight was measured without shoes and with only light clothing, to the nearest 0.1 kg, on electronic scales. Body mass index (BMI) was calculated by dividing weight by height in metres squared ( $\text{kg}/\text{m}^2$ ). WC was measured with flexible anthropometric tapes to the nearest 0.1 cm at the midway point

**Table 1. Summary of data sets used for the study**

Study site (province)	Year of study	Stratum	Subject selection method	Age range (years)	Boys	Girls	Total	WC measurement position
Western Cape <sup>[16]</sup>	2006/2007	Urban	Multistage	10 - 16	196	338	534	Narrowest part of torso between ribs and iliac crest
North West <sup>[18]</sup>	2000/2001	Urban and rural	Stratified	10 - 15	431	474	905	Midway between lowest rib and iliac crest
Limpopo rural <sup>[19]</sup>	2000	Rural	Cluster	7 - 13	892	838	1 730	Midway between lowest rib and iliac crest
KwaZulu-Natal <sup>[22]</sup>	2008	Rural	Stratified	9 - 15	545	480	1 025	Narrowest point between lower costal rib and top of the iliac crest
Limpopo urban <sup>[20]</sup>	2000	Urban	Cluster	6 - 13	851	821	1 672	Midway between lowest rib and iliac crest
Mpumalanga <sup>[21]</sup>	2007	Rural	Random	1 - 20	1 097	1 155	2 252	Narrowest part of torso between ribs and iliac crest

**Table 2. Age distribution of children by sex and study site**

Study site (province)	Age (years)										
	6	7	8	9	10	11	12	13	14	15	16
<b>Boys, n</b>											
Western Cape <sup>[16]</sup>	-	-	1	12	20	12	27	22	31	39	32
North West <sup>[18]</sup>	-	-	-	-	55	89	98	63	58	68	-
Limpopo rural <sup>[19]</sup>	26	68	92	111	150	184	173	81	7	-	-
KwaZulu-Natal <sup>[22]</sup>	42	75	50	63	66	67	73	57	26	21	5
Limpopo urban <sup>[20]</sup>	6	58	96	125	92	133	127	115	62	30	7
Mpumalanga <sup>[21]</sup>	104	91	111	90	98	105	99	113	103	109	74
Total	178	292	350	401	481	590	597	451	287	267	118
<b>Girls, n</b>											
Western Cape <sup>[16]</sup>	-	-	10	17	15	47	72	62	50	44	21
North West <sup>[18]</sup>	-	-	-	-	87	80	88	73	69	77	-
Limpopo rural <sup>[19]</sup>	26	54	85	98	160	193	158	56	8	-	-
KwaZulu-Natal <sup>[22]</sup>	38	59	49	65	56	67	60	57	25	3	1
Limpopo urban <sup>[20]</sup>	4	71	108	103	102	129	127	97	56	21	3
Mpumalanga <sup>[21]</sup>	89	110	96	100	101	97	120	125	111	112	94
Total	157	294	348	383	521	613	625	470	319	257	119

- = data not available.

between the lowest rib and iliac crest, in most studies (Table 1). Median WC data of the black SA children were compared with data from African American (AA) children,<sup>[10]</sup> owing to a lack of established cutoff points for African children. The waist-to-height ratio (WHtR) was expressed as waist (cm)/height (cm). BMI *z*-scores of the children were calculated using the World Health Organization (WHO) AnthroPlus software version 1.0.4 (WHO, Switzerland).

### Statistical analysis

Statistical analysis was performed using Statistical Package for Social Sciences for Windows software version 23 (IBM, USA). Descriptive statistics (means and standard deviations) were used to present anthropometric variables based on age, sex and study sites. Differences between means based on age and study sites were tested using analysis of variance, with Bonferroni adjustments for multiple comparisons of study sites. A *p*-value <0.05 was regarded as statistically significant. Smoothed age- and sex-specific percentiles were constructed using LMS ChartMaker Pro software package (Institute of Child Health, UK).<sup>[24]</sup> The WC of the children was categorised according to the 5th, 10th, 25th, 50th, 75th, 90th and 95th percentile by age, sex and study sites. Data were pooled to construct median WC percentile curves for the whole SA data set. Age- and gender-specific median WC percentiles for all SA children were plotted on the same chart. Comparisons with AA children are presented graphically; the 50th percentile (median) was used for comparison, as only medians were available for the AA data.<sup>[10]</sup>

### Results

The anthropometric characteristics (height, weight, WC, BMI and WHtR) of the study population stratified by age, sex and study site are presented in Tables 3 and 4. Children from the Western Cape had higher values for most variables except for height and WHtR (*p*<0.05). Children from Mpumalanga were the tallest across all the age groups. Rural Limpopo children had the lowest values for all the variables except for height, which was significantly lower in urban Limpopo children (*p*<0.05). Using the WHO growth reference to classify the children and adolescents according to BMI for age *z*-scores (BMI<sub>z</sub>), the prevalence of overweight (BMI<sub>z</sub> >+1) and obesity (BMI<sub>z</sub> >+2) were 2.9% and 0.5%, respectively, in the total sample. Stratification based on sex revealed that overweight and obesity were 3.9% v. 1.8% for girls, and 0.7% v. 0.4% for boys, respectively. Further classification according to province showed that the prevalence of overweight and obesity was the highest for Western Cape children (8.9% and 2.0%, respectively), with no child being overweight or obese in rural Limpopo.

### WC percentile distribution of the children

Predictably, the WC percentile distribution of the children increased with age in both sexes (Table 5). Most of the girls with a WC at the 95th percentile were from the Western Cape, and they reached the established limit for cardiovascular risk for adult females (i.e. WC ≥80 cm)<sup>[9]</sup> from the age of 11 years onwards. At the 95th percentile, rural Limpopo children had the smallest WC. For all SA children at the different ages, boys had greater WC than girls at the 5th to 25th percentile, while girls had greater WC than boys from the 50th to the 95th percentile. Western Cape children had greater WC across almost all ages from the 50th percentile upwards, compared with children from all the other studies.

The 50th WC percentile figures of children from different study sites compared with all SA and AA children are graphically presented in Figs 1 and 2. The median WC percentile values were higher for the AA children than the SA children from different study sites for each age and sex category. Western Cape boys and girls were comparable to AA children, while children from rural Limpopo had the smallest WC of all groups. At ages 12 and 13 years, the median WC of

Mpumalanga girls was comparable to those of AA children, while Western Cape boys had comparable WC values with AA children at ages 12 and 14. When all the data sets were combined, the median WC value of SA boys and girls at 13 years old demonstrated a similar trend to AA children. At all the other ages, SA children had smaller WC than AA children.

### Smoothed WC percentile curves

The smoothed WC percentile curves for all SA children by age and sex are presented in Fig. 3. As illustrated by the curves, the 95th percentile of WC for boys ranged from 68 cm at the age of 10 years to 80 cm at 14 years. Corresponding WC percentiles for girls were 72 cm and 82 cm, respectively.

### Discussion

The present study presents data on age- and sex-specific smoothed WC percentiles for black SA children aged 10 - years. It also represents the first attempt to describe WC percentiles of black SA children with data pooled from six studies, a sample of 4 954 children (2 406 boys and 2 548 girls) in different provinces in SA.

The WC distribution of black SA children differed across studies, with urban Western Cape children having the greatest WC, and rural Limpopo children the smallest WC. Previous studies have shown that more urban SA school-age children were obese than rural children.<sup>[25]</sup> The National Food Consumption Survey also reported a higher prevalence of overweight among urban than rural children<sup>[26]</sup> based on the international BMI standard proposed.<sup>[27]</sup> The City of Cape Town is one of SA's five metropolitan municipalities and is regarded as the economic heartbeat of the Western Cape Province. It has outperformed the rest of the provinces in terms of infrastructure, income and waste disposal, whereas Limpopo Province is one of the poorest regions of SA, especially in its rural areas, with over 62% of the population living below the national poverty line.<sup>[28]</sup> Available estimates of the SA gross domestic product (GDP) data for the period between 2000 and 2009 suggest improvements in the average real annual economic growth of the different provinces. Gauteng (4%), KwaZulu-Natal (3.8%) and the Western Cape (4.3%) recorded the highest growth, while Limpopo (2.8%) recorded the least growth in GDP between 2000 and 2009.<sup>[29]</sup>

The rapid epidemiological transition currently sweeping across SA is probably having a direct impact on eating habits and lifestyle, resulting in increases in obesity in black urban populations.<sup>[30]</sup> Overconsumption of energy-dense processed foods containing high amounts of fat and sugar, and insufficient physical activity levels, are possible reasons for the rapid increase in obesity among black SA populations.<sup>[30-32]</sup> Evidence suggests that childhood obesity is increasing rapidly in SA.<sup>[33-35]</sup> Over the past decade, the prevalence of overweight and obesity among black SA children increased from 1.2 - 13.0% and 0.2 - 3.3%, respectively.<sup>[35]</sup> In a national survey of SA children and women conducted in 2005,<sup>[36]</sup> it was reported that 10.0% of children were overweight and 4.0% obese, using Cole *et al.*'s<sup>[27]</sup> BMI classification. Our data, collected between 2000 and 2008, are consistent with these reports. Consistent with our results, Senbanjo *et al.*<sup>[15]</sup> found 1.8% of children and adolescents in Nigeria to be overweight. Comparison of our data, collected over 10 years, with later studies showed an increase in the trend of overweight and obesity among children and adolescents. For instance, a longitudinal study of 6- to 9-year-olds reported that overweight and obesity in black SA children increased by 3.0% (10.3% to 13.3%) from 2010 to 2013.<sup>[34]</sup> This rapid rise in the obesity rate is a cause for concern. The increase in obesity in the later SA study<sup>[34]</sup> compared with earlier reports<sup>[35,36]</sup> may be attributed to differences in the time of data collection, owing to changing nutritional patterns over time and increased westernisation and urbanisation among the black SA population.

**Table 3. Anthropometric characteristics of boys for all study sites**

Age (yr), by study site (province)	<i>n</i>	Height (cm), mean (SD)	Weight (kg), mean (SD)	WC (cm), mean (SD)	BMI (kg/m <sup>2</sup> ), mean (SD)	WtHR, mean (SD)
<b>10</b>						
Western Cape <sup>[16]</sup>	20	136.3 (6.0)	33.6 (6.8)	61.1 (8.1)	18.0 (2.7)	0.45 (0.05)
North West <sup>[18]</sup>	55	132.8 (5.4)	28.0 (5.1)	55.9 (4.8)	15.8 (2.2)	0.42 (0.03)
Limpopo rural <sup>[19]</sup>	150	138.4 (6.4)	27.6 (3.7)	55.5 (3.5)	14.4 (1.1)	0.40 (0.02)
KwaZulu-Natal <sup>[22]</sup>	66	132.6 (7.0)	29.9 (4.8)	58.2 (3.9)	16.9 (1.6)	0.44 (0.03)
Limpopo urban <sup>[20]</sup>	92	136.6 (10.5)	30.2 (8.4)	56.5 (5.8)	15.9 (2.7)	0.41 (0.03)
Mpumalanga <sup>[21]</sup>	98	136.8 (6.2)	29.8 (4.9)	59.2 (4.4)	15.9 (1.9)	0.43 (0.03)
Total	481	136.2 (7.6)	29.17 (5.7)	57.1 (4.9)	15.6 (2.2)	0.42 (0.03)
		<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*
<b>11</b>						
Western Cape <sup>[16]</sup>	12	140.1 (4.1)	33.8 (4.4)	58.5 (6.4)	17.2 (1.8)	0.42 (0.04)
North West <sup>[18]</sup>	89	137.4 (7.3)	29.6 (4.5)	56.3 (3.7)	15.6 (1.7)	0.41 (0.02)
Limpopo rural <sup>[19]</sup>	184	142.4 (5.8)	29.7 (3.9)	56.5 (3.8)	14.6 (1.2)	0.40 (0.02)
KwaZulu-Natal <sup>[22]</sup>	67	137.6 (7.3)	32.8 (4.8)	59.4 (3.6)	17.0 (1.4)	0.43 (0.03)
Limpopo urban <sup>[20]</sup>	133	138.3 (11.6)	31.4 (9.6)	56.6 (5.9)	16.1 (2.9)	0.41 (0.04)
Mpumalanga <sup>[21]</sup>	105	142.2 (6.8)	32.9 (6.9)	60.4 (4.9)	16.2 (2.4)	0.42 (0.03)
Total	590	140.1 (8.3)	31.1 (6.5)	57.6 (4.9)	15.7 (2.2)	0.41 (0.03)
		<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*
<b>12</b>						
Western Cape <sup>[16]</sup>	27	152.6 (10.7)	46.9 (13.6)	67.3 (8.7)	19.9 (4.5)	0.44 (0.05)
North West <sup>[18]</sup>	98	142.4 (7.3)	32.8 (6.4)	58.5 (5.2)	16.1 (2.0)	0.41 (0.03)
Limpopo rural <sup>[19]</sup>	173	145.4 (7.6)	31.7 (5.3)	57.6 (4.1)	14.9 (1.5)	0.40 (0.03)
KwaZulu-Natal <sup>[22]</sup>	73	140.1 (6.6)	35.0 (6.8)	61.3 (5.3)	17.7 (2.4)	0.44 (0.03)
Limpopo urban <sup>[20]</sup>	127	142.6 (13.2)	35.3 (11.3)	58.9 (7.1)	17.0 (3.4)	0.41 (0.04)
Mpumalanga <sup>[21]</sup>	99	147.4 (7.9)	37.4 (10.4)	63.1 (6.6)	17.0 (3.1)	0.43 (0.03)
Total	597	144.3 (9.6)	34.7 (9.2)	59.8 (6.3)	16.5 (2.9)	0.41 (0.04)
		<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*
<b>13</b>						
Western Cape <sup>[16]</sup>	22	151.2 (9.2)	45.5 (16.7)	66.1 (9.8)	19.6 (5.1)	0.44 (0.05)
North West <sup>[18]</sup>	63	147.1 (7.9)	36.4 (7.3)	60.8 (4.9)	16.7 (2.2)	0.41 (0.03)
Limpopo rural <sup>[19]</sup>	81	146.8 (6.1)	32.3 (4.8)	57.5 (4.3)	14.9 (1.5)	0.39 (0.03)
KwaZulu-Natal <sup>[22]</sup>	57	147.8 (7.7)	39.8 (7.2)	63.8 (5.9)	18.1 (2.3)	0.43 (0.04)
Limpopo urban <sup>[20]</sup>	115	145.3 (14.2)	36.2 (10.9)	58.8 (6.4)	16.9 (3.5)	0.40 (0.04)
Mpumalanga <sup>[21]</sup>	113	155.9 (10.6)	44.1 (11.0)	65.7 (6.0)	17.8 (2.4)	0.42 (0.02)
Total	470	151.5 (9.2)	38.4 (10.5)	61.5 (6.8)	17.0 (2.98)	0.41 (0.03)
		<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*
<b>14</b>						
Western Cape <sup>[16]</sup>	31	159.1 (9.9)	50.8 (10.2)	67.9 (6.6)	19.9 (2.7)	0.43 (0.04)
North West <sup>[18]</sup>	58	153.0 (9.8)	41.3 (9.1)	62.0 (6.3)	17.6 (3.4)	0.41 (0.04)
Limpopo rural <sup>[19]</sup>	7	152.7 (6.1)	34.8 (3.4)	57.2 (4.0)	14.9 (0.7)	0.38 (0.04)
KwaZulu-Natal <sup>[22]</sup>	26	155.0 (8.5)	43.4 (7.0)	63.6 (3.7)	18.0 (1.5)	0.41 (0.03)
Limpopo urban <sup>[20]</sup>	62	146.1 (14.5)	37.0 (12.8)	59.0 (7.7)	16.8 (3.3)	0.40 (0.04)
Mpumalanga <sup>[21]</sup>	103	161.3 (9.4)	47.7 (10.0)	67.0 (5.4)	18.2 (2.5)	0.41 (0.03)
Total	287	155.3 (12.1)	43.7 (11.2)	63.8 (7.0)	17.8 (2.9)	0.41 (0.03)
		<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*

SD = standard deviation; WC = waist circumference; BMI = body mass index; WtHR = waist-to-height ratio.

\*Statistical significance after Bonferroni adjustments for multiple comparisons of anthropometric variables of the six study sites.

Despite government's commitment to addressing development issues in SA, large disparities in food security still exist among communities and households across the country, reflecting continuing social and economic inequalities that could be contributing to differences in the WC values of children from different locations.<sup>[38]</sup>

The comparison of the median WC values of all SA children with those of AA children revealed that the WCs of AA children of the same age and sex were greater; however, when SA groups were considered separately, Western Cape children had median WC values similar to AA children, in most instances. The differences in WC of all SA and AA children could be attributed to differences in

**Table 4. Anthropometric characteristics of girls for all the study sites**

Age (yr), by study site (province)	<i>n</i>	Height (cm), mean (SD)	Weight (kg), mean (SD)	WC (cm), mean (SD)	BMI (kg/m <sup>2</sup> ), mean (SD)	WtHR, mean (SD)
<b>10</b>						
Western Cape <sup>[16]</sup>	15	138.0 (5.8)	34.6 (5.7)	61.0 (6.5)	18.1 (2.3)	0.44 (0.05)
North West <sup>[18]</sup>	87	135.0 (8.1)	29.7 (7.6)	56.1 (6.4)	16.2 (3.1)	0.42 (0.04)
Limpopo rural <sup>[19]</sup>	160	138.4 (5.3)	27.4 (4.5)	55.1 (4.2)	14.2 (1.6)	0.40 (0.03)
KwaZulu-Natal <sup>[22]</sup>	56	133.1 (7.1)	32.0 (5.9)	59.0 (5.1)	18.0 (2.2)	0.44 (0.04)
Limpopo urban <sup>[20]</sup>	102	137.0 (10.3)	31.1 (8.7)	57.1 (7.1)	16.4 (3.2)	0.42 (0.04)
Mpumalanga <sup>[21]</sup>	101	139.6 (6.8)	33.1 (8.2)	60.1 (6.5)	16.8 (3.0)	0.43 (0.04)
Total	521	137.2 (7.7)	30.3 (2.3)	57.2 (6.2)	15.9 (2.9)	0.42 (0.04)
		<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*
<b>11</b>						
Western Cape <sup>[16]</sup>	47	144.3 (7.1)	41.5 (9.3)	65.3 (9.1)	19.8 (3.9)	0.45 (0.06)
North West <sup>[18]</sup>	80	141.1 (6.5)	34.7 (8.8)	59.4 (8.4)	17.3 (3.5)	0.42 (0.05)
Limpopo rural <sup>[19]</sup>	193	143.6 (6.1)	30.3 (5.5)	56.7 (4.2)	14.6 (1.8)	0.40 (0.03)
KwaZulu-Natal <sup>[22]</sup>	67	139.0 (7.0)	37.3 (8.8)	62.2 (7.3)	19.2 (3.4)	0.45 (0.05)
Limpopo urban <sup>[20]</sup>	129	138.8 (11.8)	30.9 (9.9)	56.7 (6.5)	15.8 (3.0)	0.41 (0.04)
Mpumalanga <sup>[21]</sup>	97	146.2 (7.4)	36.6 (9.2)	61.8 (7.4)	17.0 (3.3)	0.42 (0.04)
Total	613	142.2 (8.5)	33.6 (8.9)	59.1 (7.2)	16.5 (3.4)	0.42 (0.05)
		<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*
<b>12</b>						
Western Cape <sup>[16]</sup>	72	149.6 (7.2)	47.6 (14.2)	68.7 (11.3)	21.0 (4.8)	0.46 (0.06)
North West <sup>[18]</sup>	88	145.4 (8.6)	36.2 (8.2)	59.8 (5.9)	17.0 (2.7)	0.41 (0.03)
Limpopo rural <sup>[19]</sup>	158	148.1 (7.0)	33.5 (5.8)	57.4 (4.4)	15.2 (1.8)	0.40 (0.03)
KwaZulu-Natal <sup>[22]</sup>	60	143.9 (5.9)	41.0 (9.7)	63.6 (7.2)	19.6 (3.6)	0.44 (0.04)
Limpopo urban <sup>[20]</sup>	127	140.5 (15.1)	33.2 (11.3)	57.4 (6.8)	16.4 (2.9)	0.41 (0.04)
Mpumalanga <sup>[21]</sup>	120	153.1 (7.4)	47.6 (12.3)	68.7 (8.3)	20.1 (4.0)	0.45 (0.04)
Total	625	146.9 (10.3)	38.9 (11.9)	61.8 (8.7)	17.7 (3.9)	0.42 (0.05)
		<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*
<b>13</b>						
Western Cape <sup>[16]</sup>	62	153.4 (7.7)	50.5 (10.2)	68.8 (7.2)	21.4 (3.7)	0.45 (0.04)
North West <sup>[18]</sup>	73	149.9 (7.4)	39.5 (8.6)	61.2 (6.0)	17.4 (2.6)	0.41 (0.03)
Limpopo rural <sup>[19]</sup>	56	150.6 (7.5)	35.8 (6.4)	57.9 (4.9)	15.7 (1.8)	0.38 (0.04)
KwaZulu-Natal <sup>[22]</sup>	57	151.0 (5.8)	48.1 (9.9)	65.7 (7.8)	21.0 (3.9)	0.44 (0.05)
Limpopo urban <sup>[20]</sup>	97	146.5 (13.1)	37.5 (11.0)	59.4 (6.4)	17.1 (3.1)	0.41 (0.04)
Mpumalanga <sup>[21]</sup>	125	155.9 (6.5)	47.8 (8.6)	67.9 (6.6)	19.6 (3.0)	0.44 (0.04)
Total	451	149.1 (11.1)	43.4 (10.8)	63.8 (7.7)	18.7 (3.6)	0.42 (0.04)
		<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*
<b>14</b>						
Western Cape <sup>[16]</sup>	50	155.2 (6.0)	54.1 (12.6)	71.0 (10.0)	22.4 (4.6)	0.46 (0.06)
North West <sup>[18]</sup>	69	153.8 (6.2)	47.4 (11.5)	65.2 (9.9)	19.9 (4.3)	0.42 (0.06)
Limpopo rural <sup>[19]</sup>	8	149.6 (7.4)	34.0 (6.2)	56.7 (5.0)	15.1 (2.0)	0.38 (0.04)
KwaZulu-Natal <sup>[22]</sup>	25	151.0 (6.4)	45.6 (5.9)	63.8 (4.1)	20.0 (2.2)	0.42 (0.03)
Limpopo urban <sup>[20]</sup>	56	148.6 (13.3)	38.1 (14.3)	60.6 (9.2)	16.8 (4.0)	0.40 (0.05)
Mpumalanga <sup>[21]</sup>	111	159.5 (6.0)	51.8 (10.8)	69.1 (7.9)	20.3 (4.1)	0.43 (0.05)
Total	319	154.8 (8.9)	47.9 (12.9)	66.2 (9.5)	19.8 (4.4)	0.43 (0.06)
		<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*	<i>p</i> <0.0001*

SD = standard deviation; WC = waist circumference; BMI = body mass index; WtHR = waist-to-height ratio.

\*Statistical significance after Bonferroni test for multiple comparison of anthropometric variables of the six study sites.

environmental factors such as lifestyle and cultural characteristics.<sup>[15]</sup> Malina *et al.*<sup>[38]</sup> observed that although human beings are generally genetically similar, populations differ in a variety of genotypic and phenotypic characteristics, including growth rates and adiposity. Tanner<sup>[39]</sup> argues that differences in size and shape between children of different populations are due to differences in their gene pools,

their environments and the interactions between the two, but with the added complications caused by variations in rates of maturation, probably due to early undernutrition. Therefore two populations may reach an average identical adult size, but the children of one population may be larger than those of the other at a particular age, simply because they have a faster rate of growth, enter puberty

**Table 5. WC percentile distribution of SA and AA boys and girls by age, sex and study site, in centimetres**

Age (yr), by study site (province)	Percentile, boys							Percentile, girls						
	5th	10th	25th	50th	75th	90th	95th	5th	10th	25th	50th	75th	90th	95th
<b>10</b>														
Western Cape <sup>[16]</sup>	52.8	54.1	56.6	58.7	61.9	77.1	83.7	52.8	53.1	56.3	60.8	67.0	72.1	*
North West <sup>[18]</sup>	50.1	50.7	52.3	55.6	57.7	61.0	65.8	49.3	50.2	51.7	54.2	59.0	63.2	72.3
Limpopo rural <sup>[19]</sup>	49.9	51.0	53.0	55.1	57.9	59.9	61.1	49.0	50.1	52.8	55.0	57.0	60.0	62.0
KwaZulu-Natal <sup>[22]</sup>	53.5	54.2	55.3	57.5	59.7	63.6	67.3	52.4	53.5	55.1	58.1	62.9	66.3	67.8
Limpopo urban <sup>[20]</sup>	48.8	50.3	52.4	55.5	59.1	63.0	70.2	48.6	50.5	52.9	55.6	59.7	64.9	72.9
Mpumalanga <sup>[21]</sup>	53.4	54.5	56.7	58.3	60.4	65.7	67.9	52.0	53.0	56.0	59.0	62.5	68.6	71.9
Total	51.4	52.5	54.4	56.8	59.5	65.0	69.3	50.7	51.7	54.1	57.1	61.3	65.8	69.4
African American <sup>[10]</sup>	-	-	-	61.3	-	-	-	-	-	-	63.0	-	-	-
<b>11</b>														
Western Cape <sup>[16]</sup>	51.5	52.1	55.6	56.5	59.9	72.4	*	53.6	56.1	59.0	63.0	70.4	79.4	82.6
North West <sup>[18]</sup>	50.4	51.9	53.7	56.4	58.9	61.3	62.7	50.8	51.8	53.8	56.9	63.3	68.9	74.5
Limpopo rural <sup>[19]</sup>	50.8	51.0	53.9	56.4	59.4	61.8	62.9	50.0	51.2	54.0	56.9	59.0	61.0	63.0
KwaZulu-Natal <sup>[22]</sup>	53.5	55.0	57.3	59.1	60.8	63.6	64.5	52.2	54.2	56.9	60.5	67.5	74.8	77.8
Limpopo urban <sup>[20]</sup>	49.4	50.6	52.9	55.6	58.6	65.1	68.1	49.5	50.5	53.0	55.8	58.8	63.0	67.0
Mpumalanga <sup>[21]</sup>	54.1	55.6	57.6	59.9	62.4	66.3	69.3	53.0	54.5	56.0	60.5	64.8	72.0	76.1
Total	51.6	52.7	55.2	57.3	59.9	65.1	65.5	51.5	53.1	55.5	58.9	63.9	69.9	73.5
African American <sup>[10]</sup>	-	-	-	63.2	-	-	-	-	-	-	65.1	-	-	-
<b>12</b>														
Western Cape <sup>[16]</sup>	57.4	57.9	61.5	65.0	72.4	77.9	89.7	55.6	57.3	60.3	65.4	76.8	87.0	89.7
North West <sup>[18]</sup>	53.6	56.1	59.0	63.0	70.4	79.4	82.6	51.4	52.2	55.8	59.2	63.7	67.7	70.2
Limpopo rural <sup>[19]</sup>	51.4	53.0	55.1	57.6	59.9	62.1	65.0	50.0	51.9	54.2	57.0	60.0	63.6	65.5
KwaZulu-Natal <sup>[22]</sup>	53.7	55.3	57.9	59.9	64.5	68.6	71.5	52.7	56.8	59.1	61.4	67.1	75.3	77.9
Limpopo urban <sup>[20]</sup>	50.4	52.1	54.0	57.7	61.9	69.6	74.5	48.2	50.0	52.5	56.3	61.0	65.1	69.9
Mpumalanga <sup>[21]</sup>	55.5	56.8	59.5	61.4	65.0	69.2	73.0	58.0	59.6	63.0	66.0	74.4	80.9	85.9
Total	53.6	52.5	54.4	56.8	59.5	65.0	69.3	50.7	51.7	54.1	57.1	61.3	65.8	76.5
African American <sup>[10]</sup>	-	-	-	65.0	-	-	-	-	-	-	67.3	-	-	-
<b>13</b>														
Western Cape <sup>[16]</sup>	56.6	57.2	58.5	63.4	68.5	79.7	96.6	58.3	61.1	64.2	67.6	72.7	78.3	82.7
North West <sup>[18]</sup>	53.6	55.4	57.5	60.2	62.4	67.2	70.4	53.7	54.5	57.1	60.4	65.2	69.6	74.2
Limpopo rural <sup>[19]</sup>	51.0	51.6	55.0	57.2	60.4	62.9	65.2	49.0	50.7	54.1	58.5	62.0	63.9	65.8
KwaZulu-Natal <sup>[22]</sup>	56.5	57.8	59.9	63.1	65.8	69.4	71.4	54.9	57.5	60.2	64.6	69.4	76.1	82.1
Limpopo urban <sup>[20]</sup>	49.5	50.5	54.0	58.6	63.0	65.6	72.4	50.0	52.0	55.5	59.0	62.1	69.0	71.7
Mpumalanga <sup>[21]</sup>	56.3	58.6	61.3	64.5	69.4	74.1	76.5	58.3	60.3	63.0	68.0	72.0	75.0	80.7
Total	53.9	55.2	57.7	61.2	64.9	69.8	75.4	54.1	56.0	58.9	63.0	67.2	71.9	76.2
African American <sup>[10]</sup>	-	-	-	67.0	-	-	-	-	-	-	69.4	-	-	-
<b>14</b>														
Western Cape <sup>[16]</sup>	55.9	60.6	63.5	68.0	71.9	77.0	82.6	59.1	61.6	63.8	69.8	74.7	81.9	96.9
North West <sup>[18]</sup>	55.2	56.7	58.9	60.5	63.2	66.7	72.0	54.2	55.4	58.4	62.4	69.9	76.9	81.6
Limpopo rural <sup>[19]</sup>	51.0	51.0	53.0	58.0	60.4	*	*	49.0	49.0	52.4	57.5	59.5	*	*
KwaZulu-Natal <sup>[22]</sup>	56.9	58.2	60.5	64.2	66.4	68.3	70.8	58.0	58.7	60.5	62.4	67.3	70.3	71.8
Limpopo urban <sup>[20]</sup>	49.2	50.4	54.3	56.9	63.0	68.9	73.2	50.4	50.9	55.4	59.3	63.1	67.2	69.3
Mpumalanga <sup>[21]</sup>	59.2	60.8	63.6	66.6	70.2	73.1	74.3	60.0	62.0	64.5	67.0	72.0	78.8	83.7
Total	54.6	56.3	58.9	62.4	65.9	70.8	74.6	55.1	56.3	59.2	63.0	67.7	75.0	80.7
African American <sup>[10]</sup>	-	-	-	68.7	-	-	-	-	-	-	71.5	-	-	-

WC = waist circumference; SA = South Africa; AA = African American; - = data not available.

\*Not possible to calculate 95th percentile owing to small number in this age group and wide variability.

earlier and reach adult body size earlier. Hence there is a need for the development of age-, sex- and population-specific WC reference cutoff points for children and adolescents.

The 80 cm internationally accepted cutoff point for WC level<sup>[9]</sup> indicating increased risk of obesity and related comorbidities for adult

females in sub-Saharan Africa was reached by Western Cape girls from 11 years of age at the 95th percentile. At 14 years old, WC at the 95th percentile in Western Cape girls even exceeded the recommended cutoff point of 92 cm for diagnosis of metabolic syndrome in adult black SA women.<sup>[40]</sup> Similarly, high median WC values were

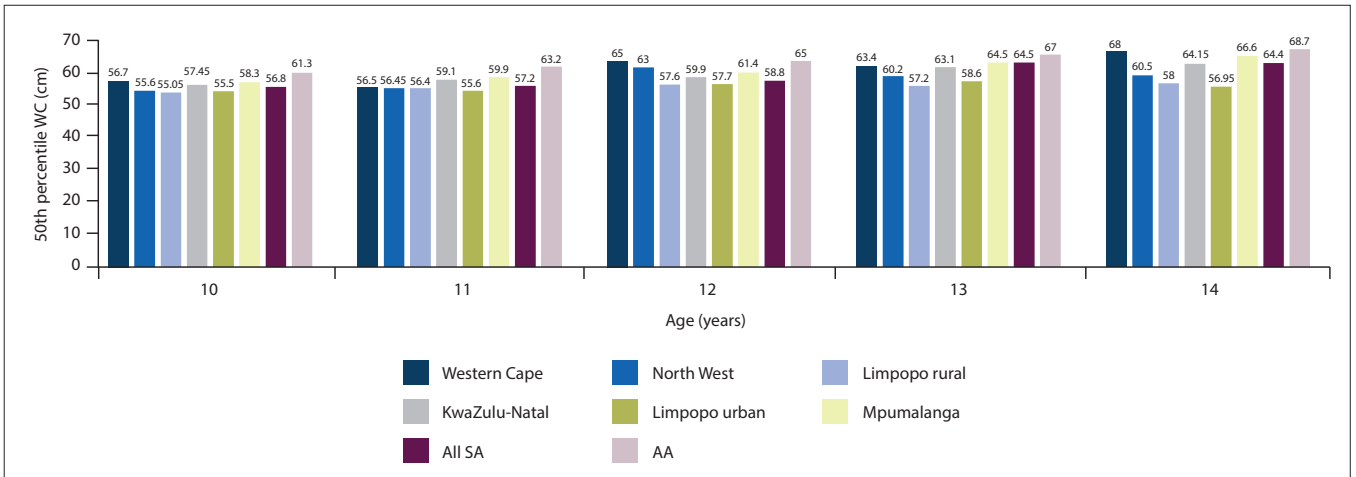


Fig. 1. Comparison of 50th waist circumference (WC) percentile value for boys from different South African (SA) study sites with African American (AA) children.<sup>[10]</sup>

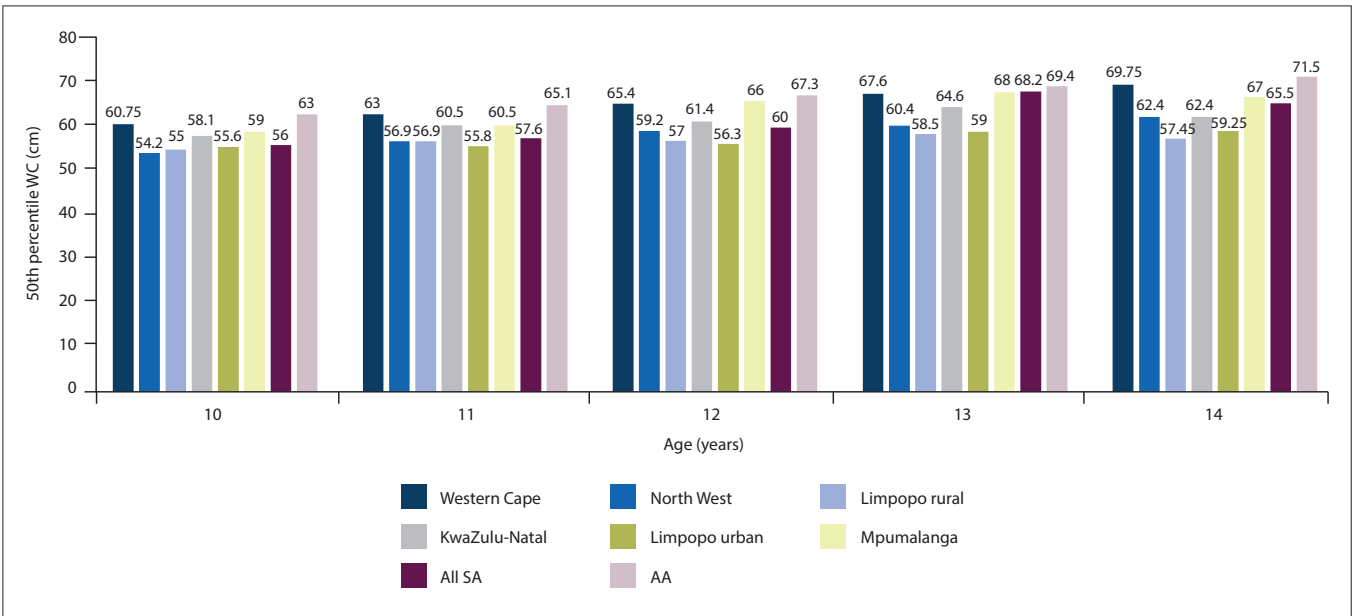


Fig. 2. Comparison of 50th waist circumference (WC) percentile value for girls from different South African (SA) study sites with African American (AA) children.<sup>[10]</sup>

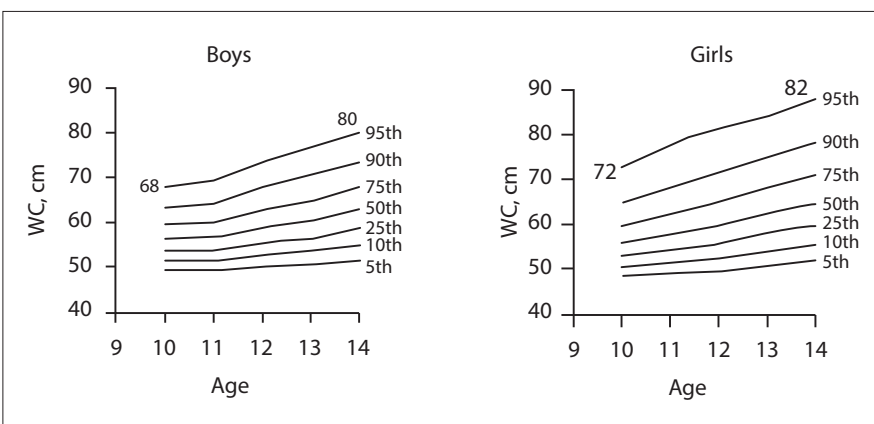


Fig. 3. Smoothed LMS curves for the 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles for waist circumference (WC) of children in all South African studies combined; boys v. girls.

evident in girls from 11 to 14 years of age in the SA study.<sup>[10]</sup> Studies in other low- and middle-income countries have reported similar findings. For example, in a study of

children and adolescents in Nigeria, it was observed that the mean WC of girls was consistently higher than that of boys from age 10 and above.<sup>[15]</sup> In contrast, studies

in high-income countries have found that boys had higher mean WC values than girls.<sup>[5,13,41]</sup> The higher WC of girls compared with boys may be explained by the earlier onset of the pubertal growth spurt in girls, which can also be associated with greater adiposity.<sup>[42-44]</sup> Disparities in WC values of children and adolescents across various countries may be attributed to genetic or racial differences in body fat distribution, as well as environmental influences such as diet, physical activity and socioeconomic changes.<sup>[35]</sup>

The high WC values are a cause for concern, and pose a potential high risk for developing obesity-related disorders in adulthood. The results clearly demonstrate the effect of sex as an important determinant of WC, hence the necessity to establish age- and sex-specific WC cutoffs.<sup>[5]</sup> Based on this, we propose WC cutoff values for abdominal obesity of 69 cm and 75 cm for adolescent boys aged 10 - 12 and 13 - 14

years, respectively. For adolescent girls aged 10 and 11 years, we propose cutoff values of 69 cm and 74 cm, respectively, while for 12 - 13 year- and 14-year-old girls, we propose cutoff values of 76 cm and 80 cm, respectively. These WC values at the 95th percentile compare favorably with those reported for 10 - 14-year-old Nigerian children and adolescents.<sup>[15]</sup> Similarly, the 95th percentile values of WC reported for Indian boys and girls were also comparable to those in the present study.<sup>[45]</sup>

A strength of this study is the large sample size, selected from a sample of black children drawn from the low- and middle-income socioeconomic classes from five out of nine provinces in SA. A potential limitation is that the anatomical sites for WC measurement differed slightly in the data sets. Three out of the six data sets measured WC according to WHO guidelines (i.e. midpoint between lower costal margin and iliac crest). There is, however, currently no consensus on which anatomical site is optimal in children and adolescents.<sup>[46]</sup> Therefore, a standardised site should be recommended internationally for WC measurement to better assess and compare cardiovascular risks. The study is also limited by differences in the year of data collection by the different studies and in sample selection methods, and the absence of data on environmental factors such as diet and lifestyle, which might have allowed for a comprehensive discussion of our results.

Changes in typical body size and shape, including WC, have been reported to occur in children over recent years, and may be a consideration when comparing data collected in different periods.<sup>[47]</sup> It is therefore possible that the median WC values obtained by the studies at different times may reflect a trend towards increasing WC with improvements in the general socioeconomic status of the different provinces in SA, as demonstrated by the smaller WC found in the studies in which data were collected during 2000 and 2001, compared with WC data collected 6 - 8 years later.

## Conclusion

The present study is the first study to construct smoothed WC percentile curves for a population of black SA children aged 10 - 14 years. The results show that the median WC of all SA black children is smaller than that of AA children; however, the median WC values of children from the Western Cape come close to those of AA children, followed by children from KwaZulu-Natal and Mpumalanga. The estimated percentile curves, however, describe the population represented, and do not establish a standard of what WC percentiles of black SA children should ideally be. The information can, however, be used as a point of reference for future studies on developing WC cutoffs in the paediatric population. The need for national data to develop ethnic-specific cutoff points for the identification of at-risk children and adolescents should be given priority, considering the increasing levels of childhood obesity worldwide. International agreement is needed regarding the optimal WC measurement site for meaningful comparisons among children and adolescents across different countries and regions.

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EK-M, KDM, CMS, MEvS, MF and HSK edited the draft manuscript and all authors read and approved the final manuscript.

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