POPULATION STUDY ARTICLE

Body mass index classification misses to identify children with an elevated waist-to-height ratio at 5 years of age

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BACKGROUND: Abdominal adiposity is an important risk factor in the metabolic syndrome. Since BMI does not reveal fat distribution, waist-to-height ratio (WHtR) has been suggested as a better measure of abdominal adiposity in children, but only a few studies cover the preschool population. The aim of the present study was to examine BMI and WHtR growth patterns and their association regarding their ability to identify children with an elevated WHtR at 5 years of age.

METHODS: A population-based longitudinal birth cohort study of 1540 children, followed from 0 to 5 years with nine measurement points. The children were classified as having WHtR standard deviation scores (WHtR_{SDS}) <1 or ≥1 at 5 years. Student's *t*-tests and Chi-squared tests were used in the analyses.

RESULTS: Association between BMI_{SDS} and WHtR_{SDS} at 5 years showed that 55% of children with WHtR_{SDS} ≥1 at 5 years had normal BMI_{SDS} (*p* < 0.001). Children with WHtR_{SDS} ≥1 at 5 years had from an early age significantly higher mean BMI_{SDS} and WHtR_{SDS} than children with values <1.

CONCLUSIONS: BMI classification misses every second child with WHtR_{SDS} ≥1 at 5 years, suggesting that WHtR adds value in identifying children with abdominal adiposity who may need further investigation regarding cardiometabolic risk factors.

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INTRODUCTION

The number of overweight or obese children has increased rapidly worldwide in recent decades.¹ Excess weight in childhood and adolescence has been shown to be associated with the metabolic syndrome (MetS),² and according to one recent update, ~10% of children and adolescents have this syndrome.³ The MetS represents a number of cardiometabolic risk factors: obesity (predominantly abdominal), hypertension, insulin resistance, glucose intolerance and dyslipidaemia, which are all related to an increased risk of cardiovascular morbidity.^{4,5} Cardiometabolic risk factors have been found to exist already during preschool age, at the onset of overweight or obesity⁶ and may have their origins as early as in utero.⁷

Identification of children with the MetS, as early as possible during childhood has been suggested, for the possibility to introduce lifestyle modifications early in life.^{8,9} Although there is yet no consensus regarding the definition of the MetS in children,¹⁰ abdominal adiposity is an important risk factor. In 2007, the International Diabetes Federation (IDF) presented one definition with criteria for diagnosis in children. The criteria for children in the age group 10 to <16 years were abdominal adiposity and two or more of the following risk factors: elevated blood pressure, elevated plasma glucose, elevated triglycerides and low high-density lipoprotein (HDL).¹¹ The IDF did not recommend diagnosis of the MetS in children younger than 10 years but suggested monitoring of abdominal adiposity.^{10,11} Other definitions including children as young as 2 years exist, one recently proposed by Ahrens et al.⁸ uses sex- and age-specific

cutoff values for the different components of the MetS, and also in their definition, particular weighting is given to waist circumference.

Since children with obesity have a higher risk of developing the MetS, compared to children without obesity, it may be advantageous to screen for the MetS in children with excess weight.³ Although the prevalence of the MetS in children has increased, it is still relatively low, and it would not be cost effective to perform blood tests for cardiometabolic risk factors in all children at risk, therefore anthropometric measures have been suggested as good alternatives in screening.^{12,13}

Body mass index (BMI) is the most commonly used surrogate measure of adiposity in children and in adults.¹⁴ Nevertheless, the value of BMI in cardiometabolic risk screening has been questioned since it does not distinguish between fat mass and fat-free mass.¹⁵ BMI also has a low correlation with fat distribution such as abdominal fat.¹⁶ Since abdominal adiposity is the most prevalent of the cardiometabolic risk markers, and its presence is a sign of disturbed fat metabolism,¹⁷ a measure that better relates to abdominal adiposity would be valuable in this screening.

Waist circumference (WC) and waist-to-height ratio (WHtR) have been suggested as surrogate measures of cardiometabolic risk factors and abdominal adiposity in children and adolescents.^{18–22} However, only a few studies cover the utility of BMI and WHtR in identifying abdominal adiposity in preschool children.^{23,24}

The aim of the present study was to examine if BMI and WHtR growth patterns from an early age could identify children with an elevated WHtR at 5 years of age by using standard deviation score

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(s) (SDS) in children classified according to WHtR_{SDS} at 5 years of age. The second aim was to study the association between BMI_{SDS} and WHtR_{SDS} at 5 years of age, with the hypothesis that an elevated WHtR partly identifies other children than an elevated BMI does.

METHODS

Study population and design

The present study is a longitudinal birth cohort study with a 5-year perspective, part of the ongoing population-based birth cohort study, the Halland Health and Growth Study (H²GS). The aim of the H²GS is to study factors that affect health and growth in children. From its start, the H²GS included 2666 children (1349 boys and 1317 girls), born in the south-western part of Sweden in the county of Halland between 1 October 2007 and 31 December 2008. All 3860 children born in the county within this time period, and visiting the child health care centers, were eligible to take part in the study without any exclusions. The families were recruited when visiting the child health care centers for the first time. Measurements of height, weight, and WC were collected at nine points, beginning at the age of 0–1 month. In connection with each visit, the parents filled in questionnaires regarding their child's lifestyle and food habits, as well as background data. The study protocol, the representativeness of the sample, and the recruitment process were reported in detail elsewhere.²⁵

In this part of the study, only children with complete growth data at 5 years of age were included. Due to lack of these data, 437 boys and 385 girls were excluded, as were children measured outside our decided age limits. For children below 12 months of age we used ± 1.5 months, except at the measurement point 0–1 month (where 0–45 days was used instead). From 12 months of age, we used ± 2.5 months. This excluded another 132 boys and 114 girls. In addition, children born preterm were excluded, 35 boys and 31 girls. As 3 girls and 5 boys were both measured outside the selected age limit and born preterm, and because they only were excluded once, the total remaining study population consisted of 750 boys and 790 girls. This study was approved by the regional ethical review board in Lund, Sweden (DNR: 299/2007). Written informed consent was obtained from the parents of all the participating children.

Measurements

Measurements of height, weight, and WC were done at 0–1, 3–4, 6, 12, 18, 24, 36, 48, and 60 months. All measuring was performed by trained child health care nurses. Stadiometers were used for measuring height. In children below 2 years of age, height was measured in a supine position, and after 2 years of age in a standing position (without shoes). Infants below 15 kg were weighed on baby scales in a supine position and thereafter on step scales, mechanical or electronic. Younger children were weighed without clothing and older children in underpants. WC was measured midway between the lowest rib and the top of the iliac crest, at the end of a gentle expiration (without clothing). In children below 2 years of age, WC was measured in a supine position and thereafter in a standing position. Within the framework of the project, the inter- and intra-operator reliability for WC has been studied in children mainly younger than 24 months. The intra-class correlation coefficients were 0.98 both within and between those who made the measurements, although one of the persons was less experienced.

BMI was calculated as weight (kg)/(height in m)² and was then transformed into age- and gender-specific SDS, using the estimated mean and standard deviation (SD) functions based on Swedish reference data.²⁶ SDS represents the difference between the observed and estimated mean BMI divided by the SD, and with regard to age and gender. WHtR was calculated as WC (cm)/height (cm) and was then transformed into age- and

gender-specific SDS using the estimated mean and standard deviation functions based on Swedish reference data.²⁷

Classifications

The children were classified as having WHtR_{SDS} <1 or ≥ 1 at 60 months of age according to Swedish reference values.²⁷ In this population a WHtR_{SDS} of 1 corresponded to a crude WHtR value of 0.51 in both boys and girls. For associations between BMI_{SDS} and WHtR_{SDS} at 60 months, the children were also classified as having BMI_{SDS} either for normal weight (including underweight) or overweight/obesity according to BMI cutoff values by the International Obesity Task Force (IOTF),²⁸ which were transformed to corresponding BMI_{SDS}: 1.26 and 1.20 for overweight and 2.44 and 2.22 for obesity, in boys and girls, respectively (corresponding SDS for underweight, the second grade of thinness, were -2.44 and -2.22 for boys and girls, respectively).

Birth weight, birth length as well as gestational age were collected from the Swedish medical birth register. Children were classified as small for gestational age (SGA), appropriate for gestational age (AGA) or large for gestational age (LGA). SGA was defined as birth weight or birth length ≤ -2 SDS for gestational age, and LGA was defined as birth weight or birth length ≥ 2 SDS for gestational age, according to Swedish reference standards.²⁹

Statistics

Student's *t*-tests were performed to compare the mean values of BMI_{SDS} and WHtR_{SDS} at the different measurement points in the WHtR_{SDS} groups (BMI_{SDS} <age>, WHtR_{SDS} <age>). Chi-squared tests were made for the study of associations between BMI_{SDS} and WHtR_{SDS} at 60 months. In all statistical analyses except for the Chi-squared tests boys and girls were analysed separately.

IBM SPSS Statistics (IBM Corp, Armonk, New York, v.20.0) was used for all statistical analyses. A *p*-value <0.05 was considered statistically significant. Conversions of crude values to BMI_{SDS} and WHtR_{SDS}, as well as the construction of graphs were made in Matlab (The MathWorks, Natick, Massachusetts v.9.0.0.341360R2016a).

RESULTS

Of the 750 boys, 86.8% had WHtR_{SDS}<1 and 13.2%, had values ≥ 1 , at 5 years of age (Table 1). The corresponding values for the 790 girls were 83.3%, and 16.7%, respectively.

WHtR_{SDS} values ≥ 1 at 5 years corresponded to crude WHtR values between 0.51 and 0.59 in the boys and between 0.51 and 0.66 in the girls. BMI_{SDS} classification showed that among the boys, 2.4% had underweight, 87.6% had normal weight, 8.5% had overweight, and 1.5% had obesity. The corresponding values for the girls were, 1.6, 85.7, 9.6, and 3.0%. Mean values of BMI and BMI_{SDS} were at 5 years significantly higher in children with WHtR_{SDS} ≥ 1 compared to in children with WHtR_{SDS} <1 (*p* < 0.001). There were no significant differences in mean birth weight (MBW) and proportion of children born SGA or LGA between the different WHtR_{SDS} groups.

Association between BMI_{SDS} and WHtR_{SDS}

Overweight/obesity according to BMI_{SDS} was to a high proportion associated with an elevated WHtR_{SDS}, where 104/175 (59%) children with overweight/obesity according to BMI_{SDS} had ≥ 1 in WHtR_{SDS}. However, 127/1365 (9%) of children with normal weight according to BMI_{SDS} had ≥ 1 in WHtR_{SDS}, representing 55% of all children with WHtR_{SDS} ≥ 1 (*p* < 0.001) (Table 2). In these 55% of the children, the crude WHtR values were between 0.51 and 0.56 compared to 0.51 and 0.66 in the group with overweight/obesity and WHtR_{SDS} ≥ 1 .

In further analyses, we compared the subgroup of children with normal weight according to BMI_{SDS} and ≥ 1 in WHtR_{SDS} at 5 years, to children with overweight/obesity and ≥ 1 in WHtR_{SDS} at the

Table 1. Characteristics of the study population by gender

WHtR _{SDS} , boys (n = 750)	<1 SD (n = 651)	≥1 SD (n = 99)
At birth		
MBW ± SD (g)	3685 ± 462	3654 ± 499 ns
Missing (n)	37	5
Size for gestational age		
SGA (n)	26	3
AGA (n)	593	94
LGA (n)	31	2
Missing (n)	1	0
Gestational age		
37 ⁰ –37 ⁶ (n)	32	4
38 ⁰ –40 ⁶ (n)	472	73
41 ⁰ –43 ⁵ (n)	147	22
Missing (n)	0	0
Maternal age		
<25 (n)	75	9
25–35 (n)	422	67
≥35 (n)	150	22
Missing (n)	4	1
At 60 months, mean ± SD		
BMI (kg/m ²)	15.40 ± 1.1	17.36 ± 1.4***
BMI _{SDS}	−0.40 ± 1.0	1.16 ± 0.9***
WHtR (cm/cm)	0.47 ± 0.0	0.53 ± 0.0***
WHtR _{SDS}	−0.42 ± 0.9	1.55 ± 0.5***
WHtR _{SDS} , Girls (n = 790)	<1 SD (n = 658)	≥1 SD (n = 132)
At birth		
MBW ± SD (g)	3546 ± 448	3499 ± 452 ns
Missing (n)	25	6
Size for gestational age		
SGA (n)	14	5
AGA (n)	618	120
LGA (n)	26	5
Missing (n)	0	1
Gestational age		
37 ⁰ –37 ⁶ (n)	24	9
38 ⁰ –40 ⁶ (n)	486	95
41 ⁰ –43 ⁵ (n)	148	28
Missing (n)	0	0
Maternal age		
<25 (n)	54	12
25–35 (n)	443	89
≥35 (n)	153	29
Missing (n)	8	2
At 60 months, mean ± SD		
BMI (kg/m ²)	15.30 ± 1.1	17.37 ± 1.8***
BMI _{SDS}	−0.22 ± 0.9	1.16 ± 0.9***
WHtR (cm/cm)	0.47 ± 0.0	0.53 ± 0.0***
WHtR _{SDS}	−0.23 ± 0.8	1.58 ± 0.5***

For mean values in birth weight, BMI, BMI_{SDS}, WHtR, and WHtR_{SDS}, the groups with WHtR_{SDS} ≥1 at 5 years of age were compared with the groups with <1, ***p < 0.001, ns non-significant
MBW mean birth weight, SD standard deviation, SGA small for gestational age, AGA appropriate for gestational age, LGA large for gestational age, BMI_{SDS} body mass index standard deviation scores, WHtR_{SDS} waist-to-height ratio standard deviation scores

Table 2. Correlation between WHtR_{SDS} and BMI_{SDS} in children at 60 months of age

WHtR _{SDS} ^a n = 1540	<1 SD n = 1309	≥1 SD n = 231
BMI _{SDS} Nw ^b (n)	1238 (94.6%)	127 (55%)
BMI _{SDS} Ow/Ob (n)	71 (5.4%)	104 (45%)

WHtR_{SDS} waist-to-height ratio standard deviation scores, BMI_{SDS} body mass index standard deviation scores, Nw normal weight, Ow/Ob overweight/obesity
^aChi-squared tests of the association between BMI_{SDS} and WHtR_{SDS}. The children were classified as having <1 or ≥1 in WHtR_{SDS} according to Swedish reference values at 60 months of age,²⁷ and as having BMI_{SDS} for normal weight/underweight or overweight/obesity at 60 months of age, according to BMI cutoff values by the International Obesity Task Force²⁸
^bIncluding children with underweight

same age. We found that the group of children with normal BMI_{SDS} and elevated WHtR_{SDS} had a significantly lower mean birth weight, 3504 g vs. 3725 g ($p < 0.001$), and 56% of the children were girls compared to 59% girls ($p = 0.143$) in the group with overweight/obesity and an elevated WHtR_{SDS}. When comparing the growth patterns between 0 and 5 years in the two groups, it was shown that the subgroup of children with normal weight according to BMI_{SDS} and an elevated WHtR_{SDS} had lower mean BMI_{SDS} values ($p < 0.05$) at every measurement point when compared to the children with overweight/obesity and an elevated WHtR_{SDS}. Their mean BMI_{SDS} passed 1, the cutoff for overweight only at the 3–4 months measurement point, compared to at 3–4, 36, 48, and 60 months in the group with overweight/obesity and an elevated WHtR_{SDS}. The mean WHtR_{SDS} values in the two groups differed significantly first at the last two measurement points where the group with overweight/obesity and an elevated WHtR_{SDS} had higher values ($p < 0.05$).

BMI_{SDS} growth patterns for children with normal or elevated WHtR_{SDS} at 5 years of age

Boys and girls with WHtR_{SDS} ≥1 at 5 years of age had significantly higher mean BMI_{SDS} than children with <1 in WHtR_{SDS} at every measurement point. The boys passed the 1 SDS line at ~48 months and the girls passed it at ~54 months (Fig. 1, Table 3). Children with <1 in WHtR_{SDS} remained relatively stable at all measurement points without any upward SDS line crossing.

In the BMI_{SDS} graphs, both boys and girls in both of the WHtR_{SDS} groups had a peak in BMI_{SDS} at the 3–4 months measurement point (Fig. 1).

WHtR_{SDS} growth patterns for children with normal or elevated WHtR_{SDS} at 5 years of age

Children with WHtR_{SDS} ≥1 at 5 years of age had significantly higher mean WHtR_{SDS} than children with <1 in WHtR_{SDS} at every measurement point, except at the first measurement point in the girls. The boys crossed the 1 SDS line between 36 and 48 months and the girls crossed it at ~48 months. (Fig. 1, Table 4). Children with <1 in WHtR_{SDS} remained relatively stable at all measurement points without any upward SDS line crossing.

DISCUSSION

In the present study, consisting of 1540 Swedish preschool children we examined BMI_{SDS} and WHtR_{SDS} growth patterns and their association, in children classified according to WHtR_{SDS} at 5 years of age. The main finding was that 55% of children with WHtR_{SDS} ≥1 at 5 years of age had normal BMI_{SDS}. This may be worrying, since in children 6 years and older, a WHtR value of

Fig. 1 Growth patterns based on mean body mass index standard deviation scores (BMI_{SDS}) (**a, b**) and mean waist-to-height ratio standard deviation scores (WHR_{SDS}) (**c, d**) from 0 to 60 months and by gender, in children classified according to Swedish WHR_{SDS} reference values at 60 months of age.²⁷ Blue lines represent children with $WHR_{SDS} \geq 1$, green lines represent children with $WHR_{SDS} < 1$ at 5 years

0.5 has been recommended as a cutoff for central obesity and cardiometabolic risk factors.^{19,21} All children with $WHR_{SDS} \geq 1$ in our study had crude WHtR values ≥ 0.51 . Khoury et al.,³⁰ recently showed that children aged 5–18 years had a worsened cardiometabolic risk and a higher frequency of cardiometabolic risk factors, with increasing values in WHtR. In their study, the children were classified into three groups based on WHtR values, < 0.5 , 0.5 to < 0.6 and ≥ 0.6 . Since the children in our study with $WHR_{SDS} \geq 1$ all had values ≥ 0.51 , also children in our cohort may have risk factors associated with abdominal adiposity.

When studying BMI_{SDS} and WHR_{SDS} growth patterns, we found that children with $WHR_{SDS} \geq 1$ at 5 years had significantly higher mean BMI_{SDS} and WHR_{SDS} from an early age, when compared to children with values below 1. This shows that some correlation between WHtR and BMI exist during the 5-year period.

When specifically studying BMI_{SDS} growth patterns in the subgroup of children with a normal BMI_{SDS} and an elevated WHR_{SDS} at 5 years, it was shown that they had lower mean BMI_{SDS} at every measurement point in comparison with children with overweight/obesity and an elevated WHR_{SDS} . They passed 1 SDS in BMI only at the 3–4 months measurement point. This suggests that BMI besides being unable to identify most of the children with an elevated WHR_{SDS} at 5 years, also failed to identify them at most of the time points during the 5-year period.

Our study indicates that when BMI is used alone as a measure of overweight and obesity, children with elevated waist-to-height ratio who may need further investigation regarding cardiometabolic risk factors may be missed. This is in line with studies that have found WHtR to be better than BMI in assessing cardiometabolic risk factors.^{21,30,31} There are also studies that contradict these results.^{32,33} The benefits with the use of WHtR may also differ in children with overweight compared with those in children with obesity. Morandi et al. have shown that WHtR, WC, BMI, and Z-BMI

were not good predictors of metabolic impairments in obese adolescents.³⁴ Future studies in preschool children may reveal if this applies to children with obesity in this age group as well.

The association between cardiometabolic risk factors and abdominal adiposity in preschool children is not clear. In school children, insulin sensitivity has been shown to be negatively correlated with abdominal subcutaneous adipose tissue (SAT) and not with abdominal visceral adipose tissue (VAT),³⁵ suggesting that abdominal SAT is an important risk factor. In 5-year-old children, measurements of WC have been shown to correlate with abdominal SAT but not with VAT when verified by MRI.³⁶ This indicates that WHtR may be an important measure in early identification of children who may need further investigation regarding cardiometabolic risk factors. The measurements and calculations needed for WHtR are easily made and reproduced,^{14,19,37} and anthropometric measures are cost effective alternatives in screening of individuals at risk for the MetS.^{12,13}

Our results indicate that WHtR in preschool children adds value regarding identification of central obesity, which represents an important risk factor in the MetS. The MetS have been shown to originate already at the onset of overweight or obesity in young children,^{6,38} and screening for risk factors during preschool age have recently been suggested in other studies as well.^{6,8} However, more studies regarding the association between abdominal fat associated with cardiometabolic risk factors are needed in the youngest children. Since the cutoff value 0.5 in WHtR for central obesity associated with cardiometabolic risk is recommended for children 6 years and older, clinically relevant values for children below 6 years are needed as well.

Since it has been shown earlier that children born SGA often develop central obesity later in life,³⁹ we expected a higher proportion of children born SGA in the $WHR_{SDS} \geq 1$ groups than in the other groups, this was not the case, and may depend on the

Table 3. Mean differences in BMI_{SDS} over time and by gender between combinations of children with WHtR_{SDS} ≥ 1 or < 1 at 60 months of age

WHtR _{SDS}	≥ 1 SD vs. <1 SD ^a		<i>p</i>
	Mean difference	(95% CI)	
BMI _{SDS} , boys			
BMI _{SDS} 0–1 mo	0.38	(0.16–0.60)	0.001
BMI _{SDS} 3–4 mo	0.43	(0.21–0.64)	<0.001
BMI _{SDS} 6 mo	0.81	(0.58–1.04)	<0.001
BMI _{SDS} 12 mo	0.93	(0.71–1.15)	<0.001
BMI _{SDS} 18 mo	1.00	(0.82–1.18)	<0.001
BMI _{SDS} 24 mo	1.11	(0.88–1.34)	<0.001
BMI _{SDS} 36 mo	1.11	(0.89–1.33)	<0.001
BMI _{SDS} 48 mo	1.40	(1.16–1.63)	<0.001
BMI _{SDS} 60 mo	1.56	(1.35–1.77)	<0.001
BMI _{SDS} , girls			
BMI _{SDS} 0–1 mo	0.28	(0.09–0.48)	0.005
BMI _{SDS} 3–4 mo	0.49	(0.31–0.67)	<0.001
BMI _{SDS} 6 mo	0.58	(0.38–0.78)	<0.001
BMI _{SDS} 12 mo	0.73	(0.54–0.93)	<0.001
BMI _{SDS} 18 mo	0.74	(0.54–0.94)	<0.001
BMI _{SDS} 24 mo	0.94	(0.73–1.15)	<0.001
BMI _{SDS} 36 mo	1.04	(0.84–1.24)	<0.001
BMI _{SDS} 48 mo	1.01	(0.81–1.20)	<0.001
BMI _{SDS} 60 mo	1.39	(1.21–1.56)	<0.001

^aStudent's *t*-tests were used to compare groups of children with WHtR_{SDS} ≥ 1 or < 1 according to Swedish reference values²⁷
Vs versus, 95% CI 95% confidence interval, *p* *p*-value, BMI_{SDS} body mass index standard deviation scores, *mo* months

Table 4. Mean differences in WHtR_{SDS} over time and by gender between combinations of children with WHtR_{SDS} ≥ 1 or < 1 at 60 months of age

WHtR _{SDS}	≥1 SD vs. <1 SD ^a		<i>p</i>
	Mean difference	(95% CI)	
WHtR _{SDS} , boys			
WHtR _{SDS} 0–1 mo	0.39	(0.17–0.60)	0.001
WHtR _{SDS} 3–4 mo	0.44	(0.23–0.65)	<0.001
WHtR _{SDS} 6 mo	0.71	(0.48–0.93)	<0.001
WHtR _{SDS} 12 mo	0.81	(0.57–1.04)	<0.001
WHtR _{SDS} 18 mo	0.87	(0.64–1.10)	<0.001
WHtR _{SDS} 24 mo	0.96	(0.73–1.19)	<0.001
WHtR _{SDS} 36 mo	1.11	(0.91–1.31)	<0.001
WHtR _{SDS} 48 mo	1.23	(1.02–1.45)	<0.001
WHtR _{SDS} 60 mo	1.97	(1.85–2.08)	<0.001
WHtR _{SDS} , Girls			
WHtR _{SDS} 0–1mo	0.17	(–0.05–0.38)	0.131
WHtR _{SDS} 3–4 mo	0.48	(0.28–0.68)	<0.001
WHtR _{SDS} 6 mo	0.58	(0.39–0.77)	<0.001
WHtR _{SDS} 12 mo	0.60	(0.40–0.80)	<0.001
WHtR _{SDS} 18 mo	0.66	(0.46–0.87)	<0.001
WHtR _{SDS} 24 mo	0.89	(0.67–1.11)	<0.001
WHtR _{SDS} 36 mo	1.00	(0.83–1.16)	<0.001
WHtR _{SDS} 48 mo	1.05	(0.87–1.24)	<0.001
WHtR _{SDS} 60 mo	1.80	(1.69–1.91)	<0.001

^aStudent's *t*-tests were used to compare groups of children with WHtR_{SDS} ≥ 1 or < 1 according to Swedish reference values²⁷
Vs versus, 95% CI 95% confidence interval, *p* *p*-value WHtR_{SDS} waist-to-height ratio standard deviation scores, *mo* months

relatively small number of children born SGA in these groups due to the population-based design of the study.

The peak in BMI_{SDS} that was observed in the BMI_{SDS} graphs at 3–4 months in both boys and girls indicates a difference at that age between the Swedish reference and the study population. This difference was also observed in another Swedish study, who compared their data with the current Swedish BMI reference.⁴⁰ The reason for this difference is not yet clear, it may be due to smoothing of the data in the Swedish reference or due to a secular trend in the studied population compared to the reference population.

A major limitation of the current study was our absence of measures of body fat distribution for validation of WHtR and BMI in this child cohort. We also lack data regarding cardiometabolic risk factors. This information would have been able to confirm if children with an elevated WHtR had signs of the MetS already at these young ages. Another limitation of the current study was that we had to exclude children because of missing growth data or because they were measured outside our decided age limit, they could represent a possible bias. This was mainly due to the inclusion of only measurements close to the measurement points, and wider limits for this would affect precision. The main strength of this study was the population-based longitudinal design, as longitudinal studies of BMI and WHtR in the preschool population still are limited.

In conclusion, we found that every second child with a WHtR_{SDS} of ≥ 1 at 5 years of age were normal weight according to BMI_{SDS}. Our results indicate that WHtR to a large extent identifies other children than BMI does. Abdominal adiposity is an important risk factor in the metabolic syndrome, and it has been shown in other

studies that children as young as 5 years with elevated WHtR may have cardiometabolic risk factors. Therefore, our results suggest that WHtR adds value in identifying children with abdominal adiposity who may need further investigation regarding cardiometabolic risk factors.

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AUTHOR CONTRIBUTIONS

Each author has met the *Pediatric Research* authorship requirements. J.R., J.D., G.A.T., B.A., S.B., A.B., C.S.N., and A.L. have contributed substantially to conception and design of the study. J.R., J.D., G.A.T., B.A., and S.B. have contributed substantially to the acquisition of data. A.L., J.R., J.D., and S.B. have analysed and interpreted the data. All authors have revised the manuscript critically for important intellectual content and have had final approval of the version to be published.

ADDITIONAL INFORMATION

Competing interests: The authors declare no competing interests.

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