Waist-to-Height Ratio as a possible Health Index for Children

Razão perímetro da cinta-altura como um possível índice de saúde para crianças

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Abstract in English

Background: Central body fat has been reported to better predict risk for cardiometabolic diseases than total body fat. Recently, Waist-to-Height Ratio (WHtR) has been proposed to be a conveniently age-independent, simple and rapid screening tool for assessing this kind of risk in different populations.

Aims: To investigate whether WHtR is age or gender dependent; to describe the prevalence of Swedish children at risk using 0.5 as a cutoff point; to examine the relationship between this index and Body Mass Index (BMI).

Methods: The study was a cross-sectional design and included a random sample of 1804, 7-9 year old Swedish children (53% boys and 47% girls) from 45 primary schools. WHtR was calculated by waist circumference divided by height on the bases of standard anthropometric measurements. Independent Sample t test were performed to determine whether WHtR was gender dependent. Pearson’s correlation between WHtR and age was assessed. The number of Swedish children at risk according to this method (using 0.5 as a cutoff point) was described and these results were then compared with the number of children considered at risk by using BMI as a risk assessment tool. The level of agreement between the two indexes was obtained by Cohen’s k.

Results: No significant differences for WHtR between genders were found. There was a very week correlation between WHtR and age ($r = -0.061$, $p=0.01$). Much fewer children were considered at risk according to WHtR (6.8%) compared to BMI (22.1%). The level of agreement between these two indexes was low ($k=0.382$, $p<0.001$). Nevertheless, after merging the overweight children together with the
ones classified by BMI as having a normal weight, there was a much higher agreement between this index and WHtR (k=0.693, p<0.001).

**Conclusions:** WHtR was found to be age and gender independent in the evaluated Swedish population and therefore may be a simple health index for children. However, WHtR and BMI may produce differing predictions for disease risks. Hence, longitudinal data are needed to examine WHtR’s relation to disease.
Abstract in Portuguese

**Introdução:** É actualmente bem reconhecido que, mais importante do que a gordura corporal total no aumento do risco de doenças cardiometabólicas, é a acumulação de gordura na região abdominal. O rácio entre o perímetro da cinta e a altura (WHtR) tem sido sugerido como uma ferramenta independente da idade, simples e rápida na determinação deste tipo de risco.

**Objectivos:** Averiguar a dependência da idade e sexo no WHtR numa amostra de crianças Suecas; avaliar o número de crianças desta amostra, que segundo o WHtR se encontram em risco, usando o valor 0.5 como ponto de corte; fazer uma análise da relação existente entre o WHtR e o Índice de Massa Corporal (IMC).

**Métodos:** Estudo de desenho transversal que envolveu 1804 crianças Suecas com idade entre os 7 e os 9 anos (53% rapazes e 47% raparigas), seleccionadas de forma randomizada. O WHtR foi calculado através da divisão de duas medidas antropométricas avaliadas segundo técnicas standardizadas. Através do *Independent Sample t test*, verificou-se se havia ou não influência do sexo no WHtR. Para verificar se este índice era ou não dependente da idade calculou-se a correlação de *Pearson*. Fez-se, ainda, uma descrição do número de crianças em risco segundo o WHtR e compararam-se estes dados com aqueles obtidos pelo IMC. Para uma análise mais aprofundada da relação do WHtR e do IMC, calculou-se a sua concordância através do *kappa de Cohen*.

**Resultados:** Não foram encontradas diferenças estatisticamente significativas entre o WHtR e o sexo. Para além disso, a correlação entre o WHtR e a idade foi muito fraca (*r = - 0,061, p=0,01*). Foram muito menos as crianças consideradas em risco segundo o WHtR (6,8%) do que segundo o IMC (22,1%). A concordância
entre estes dois índices foi baixa (k=0,382, p<0.001). No entanto, esta aumentou bastante (k=0,693, p<0.001), depois de se incluírem as crianças com excesso de peso no grupo das normoponderais (sem risco) segundo o IMC.

**Conclusões:** Neste estudo, o WHtR foi considerado independente do sexo e da idade. Assim, o WHtR poderá ser um índice de saúde de aplicação fácil em crianças. No entanto, este índice e o IMC mostraram resultados bem diferentes. Logo, são necessários mais estudos, de preferência longitudinais, que relacionem este índice com o risco de complicações metabólicas e outras doenças.
Keywords in English

Waist-to-Height ratio, Body Mass Index, Children, Abdominal obesity, Risk
Keywords in Portuguese

Razão perímetro da cinta-altura, Índice de Massa Corporal, Crianças, Gordura abdominal; Risco
Introduction

It is now well known that the number of overweight and obese children is increasing dramatically. This is confirmed by the World Health Organization (WHO) who has reported it to be “an escalating epidemic, worldwide” [1, 2]. This epidemic is of great concern since it is likely that excess weight in childhood will adversely affect health in adulthood. However, deposition of intra-abdominal fat is considered more important than just total body fat, since it has been linked to cardiovascular risk factors, such as insulin resistance, hyperlipidemia and hypertension [3]. Hence, it is of high importance that methods that take central adiposity into account are used more often.

Body mass index (BMI) is a relatively simple index and the most used one to classify adults according to their amount of body fat. Nevertheless, it is not easily applied to children, does not tell us the location of the body where fat is accumulated and may not be distinguishing the weight of muscles or edema in certain individuals or ethnic group differences [4, 5]. Although Waist circumference (WC) has been internationally accepted as a reliable technique to determine deposition of fat and is used as a diagnostic criteria of metabolic complications, it does not take into consideration size of the trunk, which may differ according to sex, age and ethnicity [6]. Its cutoff values cannot be applied to the whole population - for instance, to children with metabolic syndrome risks [7].

Several studies suggest that the waist-to-height ratio (WHR), also called the index of central obesity, may be a simple and rapid screening tool for assessing health risks in different populations [8-11]. In addition, as it takes abdominal fat into consideration it appears to be more sensitive than BMI in estimating risk of future
health problems [12]. This ratio has been significantly associated with all risk factors for obesity (in both adults and children) and metabolic syndrome (in adults) [13]. Moreover, longitudinal studies have shown that it can help to predict morbidity and mortality, often better than BMI [14-16].

International cutoff points have not yet been set for WHtR, although several proposals have been suggested, mostly in Asian countries. For example, a WHtR of 0.445 was proposed as a cutoff value for both boys and girls in Han Chinese children and 0.485 for boys and 0.475 for girls in Uygur Chinese children [17]. Since WHtR adjusts for the height, it has been suggested that the same cutoff point can be used in different populations varying in sex and age. In a study of UK children and adolescents for two decades, the value 0.5 was used and considered a good cutoff indicator [18]. For this reason a simple public health message has been suggested: "keep your waist circumference to less than half of your height" [19]. This motto may be considered universal, as it may be used at any age, anywhere [18, 20]. Furthermore, studies using blood assays have reached the conclusion that 0.5 may be a good cutoff point to determine metabolic complications in both children and adults [10, 18, 21]. Indeed, it may be possible to apply it to all age groups, because the height and waist measurement increase continually with age [22]. For ease of use, WHtR has been developed into a consumer-friendly tool named Ashwell © Shape Chart [23].
The objectives of this study were:

a. to determine whether WHtR is gender and age dependent in a sample of Swedish children;

b. to investigate the proportion of Swedish children at risk for cardiometabolic disease, according to this index, using 0.5 as a cutoff point;

c. to compare these results with the information obtained by only using BMI as an index.

It is hypothesized that the WHtR may be a simple and efficient index and that it may be similarly useful to BMI in detecting children who are considered more likely to be at risk for cardiometabolic disease.
Methods

Population and sample

The data used in the present study was obtained from the WHO European Childhood growth Monitoring Surveillance Initiative [24]. The main objective of this system is to measure the trends in overweight and obesity in children aged 6.0 to 9.9 years and to get a correct notion and better control of the current obesity epidemic in Europe. Originally, fourteen countries were involved in this initiative, but the present cross sectional study focuses on Swedish data specifically. A random national representative selection of Swedish schools was done by the Statistiska Centralbyran (SBC) and then divided up for data collection and management between Karolinska Institutet and Gothenburg University. The data was collected during May, June and early July, 2008, in Sweden.

The present study used Karolinska Institute's data, one half of the representative random national sample composed of 2132 children (1st and 2nd grades) of 45 schools (northern and middle part of Sweden). From these, 84.6% (1804 children, from which 53% boys and 47% girls), aged 7, 8 and 9 were investigated in this study. The reasons for the reduction of the total number of children were: parents not consenting on the use of their child's data, the child refusing to be measured, being sick, absent or other reasons which were not reported (305 cases); exclusion of children aged 6 and 10 (13 cases); missing values for variables such as date of birth and waist circumference (9 cases) and the presence of one outlier (1 case).
Ethics

The surveillance system was implemented in accordance with the *International Ethical Guidelines for Biomedical Research Involving Human Subjects* [25]. In addition to written parental consent, each child who participated was asked for consent before being measured.

Measurements

*Height*

SECA 214 stadiometres were used to measure height. Each child was asked to stand with feet slightly apart and against the vertical backboard, straighten shoulders and place hands by their sides. It was ensured that the back of the head, shoulder blades, buttocks, calves, and heels were all touching the vertical backboard and the child’s head was at a level in which a horizontal line from the child’s ear canal to the lower border of the eye socket ran parallel to the base board with the child looking straight ahead (in accordance with the Frankfourt horizontal plane). The headboard was pulled down to rest firmly on top of the head of the child and so it compressed the hair. Height was measured in centimetres and last completed 1 millimetre (mm) [26].

*Weight*

SECA 862 digital floor scales were used for the measurement of body weight. Participants were measured wearing light clothing. The child stood in the middle of the scale, feet slightly apart and weight was recorded in kilograms nearest 100
gram unit (0.1 kg) [26].

*Waist Circumference*

To measure waist circumference SECA 200 and 201 model tapes were used. The iliac crest and lower rib margin were marked and waist circumference was measured at the level between the two marks. Measurement was taken at the end of a normal gentle expiration in centimetres to the last completed 1 millimetre (mm) (0.1 cm) [26].

*Questionnaire*

Trained staff filled in the survey protocol questionnaire (see annex 1), which included information about the child, such as name, sex, date of birth, the measurements and other details. This protocol was common to all other participating countries and included whether the child had consented verbally or not.
**Statistical analysis**

The statistical analysis was performed using Statistical Package for Social Sciences (SPSS Inc; version 16.0 for Mac).

All variables were checked for outliers. In case of suspected outliers these were rechecked again in the questionnaire and corrected or excluded from the sample (only one value of waist circumference was actually considered an outlier and was removed).

Age by month and year was established using the date of birth and the date of measurement. BMI was calculated dividing weight (kg) over squared height (m$^2$). The classification of children as having a normal weight, being overweight or obese was done according to the sex-age by month specific cut offs of the new WHO references for children [27]. When looking for differences between gender for BMI, *chi-square* test was used.

WHtR was obtained by dividing the WC (cm) by height (cm). This variable was then computed into a different variable categorized into two groups: children at risk (WHtR≥0.5) and children not at risk (WHtR <0.5).

Descriptive information of the children was calculated, including the mean, standard deviation, minimum and maximum values of age, weight, waist circumference, height and WHtR. These variables were tested for differences using the *Independent Sample t-test*.

Pearson correlation coefficients were computed to examine the association of age and BMI on WHtR.
A cross tabulation between WHtR and BMI was conducted and the level of agreement between these was obtained by applying the *Cohen’s k*. Four distinct groups were obtained and gender differences were calculated using *chi-square test* and age differences using the *One-Way ANOVA*.

BMI of the whole population was split for gender and then in each category of BMI, children at risk and not at risk according to WHtR were determined.

Significance was set at the level of 0.05.
Results

Dependency of WHtR on gender and age

More males than females were included in the sample. Descriptives for age and anthropometric measurements of the children are shown in table 1. Boys had higher values for waist circumference and height than girls (p<0.05). No significant statistical differences were found in terms of age, weight and WHtR.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Descriptives for age and anthropometric measurements by gender</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boys</td>
</tr>
<tr>
<td></td>
<td>n</td>
</tr>
<tr>
<td>Age (years)</td>
<td>952</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>29.4</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>58.2</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>133.1</td>
</tr>
<tr>
<td>WHtR</td>
<td>0.437</td>
</tr>
</tbody>
</table>

*Independent samples t-test; significant differences between males and females p < 0.05*

Mean values for WHtR at yearly intervals are shown in table 2. One-way ANOVA test showed no significant statistical differences in WHtR for this range of ages. However, a tendency for slight decrease of the mean with age was found.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Description of WHtR by age (in years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
</tr>
<tr>
<td>7.00</td>
<td>565</td>
</tr>
<tr>
<td>8.00</td>
<td>884</td>
</tr>
<tr>
<td>9.00</td>
<td>356</td>
</tr>
</tbody>
</table>
As an illustration, the relationship between age (in months) and WHtR is shown in Figure 1 (\( r = -0.061, p=0.01 \)).

**Figure 1.** Pearson’s correlation between WHtR and age (in months) (\( r = -0.061, p=0.01 \)).

**Children at risk**

In the present study 6.8% (n=122), had a WHtR equal or above 0.5 and therefore were considered at risk according to WHtR. *Chi-square test* revealed no significant differences between boys and girls. The number and percentage of boys and girls at risk are shown in table 3.
The results in Table 4 show the number of children at risk within each age group. There was a higher number of children at risk at the ages of 8 and 9, but chi-square test found no significant statistical differences.

### Table 3. Children at risk according to WHtR, split by gender

<table>
<thead>
<tr>
<th>WHtR&lt;0.5</th>
<th>WHtR&lt;0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Boys</strong></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>59</td>
</tr>
<tr>
<td>%</td>
<td>6.2</td>
</tr>
<tr>
<td><strong>Girls</strong></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>63</td>
</tr>
<tr>
<td>%</td>
<td>7.4</td>
</tr>
</tbody>
</table>

### Table 4. Children at risk according to WHtR, split by age

<table>
<thead>
<tr>
<th>WHtR&lt;0.5</th>
<th>WHtR&lt;0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>7</strong></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>29</td>
</tr>
<tr>
<td>%</td>
<td>5.1</td>
</tr>
<tr>
<td><strong>8</strong></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>67</td>
</tr>
<tr>
<td>%</td>
<td>7.6</td>
</tr>
<tr>
<td><strong>9</strong></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>26</td>
</tr>
<tr>
<td>%</td>
<td>7.3</td>
</tr>
</tbody>
</table>

**Relationship of WHtR and BMI**

Analyzing the whole population by using WHO cutoff values for BMI, 5.5% of the children were found to be obese, 16.6% were classified as overweight and 77.9% as normal.

There were no differences between the number of girls and boys classified as
normal. However, the number of obese and overweight children differed between gender (chi-square test; p<0.05). The percentage of obese boys and girls was 6.7% and 4.1%, respectively, and there were 15.4% overweight boys and 18% girls.

The relationship between WHtR and BMI is shown in figure 2. As expected, the correlation between these two variables was high (r = 0.804, p<0.001), meaning that the heavier the child the larger the waist circumference is.

![Figure 2. Pearson's correlation between WHtR and BMI (r = 0.804, p<0.001).](image)

Children were categorized into four different groups (Table 5.): one formed by the children who were not considered at risk by both indexes, one containing the children at risk according to BMI (the overweight and obese children) but not by WHtR, one formed by the children considered at risk according to WHtR and not at risk by BMI and one considering children at risk according to both indexes.

The level of agreement between these two indexes was low as shown in Table 5.
Neither gender nor age were differentiating factors between the two groups whose classification as being at risk did not match between the two indexes. These results are presented in table 5 (chi-square test was applied to search for gender differences and One Way ANOVA for age differences).

**Table 5.** Classification of children as being or not at risk according to WHtR and BMI

<table>
<thead>
<tr>
<th>According to BMI</th>
<th>According to WHtR</th>
<th>Children not at risk</th>
<th>Children at risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children not at risk</td>
<td>77.6% (n=1400)</td>
<td>15.6% (n=282)</td>
<td></td>
</tr>
<tr>
<td>Children at risk</td>
<td>0.3% (n=6)</td>
<td>6.4% (n=116)</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** Applying the Cohen’s k, the level of agreement obtained was low (k=0.382, p<0.001). There were no significant statistical differences for gender (chi-square test, p>0.05) or age (One-Way ANOVA, p>0.05) between the two groups whose classification as being at risk did not match between the two indexes.

Figure 3 illustrates all the children who are classified as being at risk or not according to WHtR, after being divided into 3 categories (normal weight, overweight and obese) according to BMI.

Amongst the boys WHtR detected only 10.9% (n=16) of the total overweight boys and 65.6% (n=42) of those considered obese by BMI. Of the girls, 18.3% (n=28) of the overweight and 85.7% (n=30) of the obese ones were considered at risk according to WHtR. Amongst the normal weight children one boy and five girls also had a WHtR ≥ 0.5.
Table 6 presents a comparison between WHtR and BMI in detecting children at risk if only obese children would be considered at risk according to BMI. Cohen’s k was applied once again and the level of agreement between the two indexes increased (good agreement). Differences between age and gender were searched for between the groups obtained, using the same tests as previously. Once again, there were no significant differences for age. However, there was a significantly higher number of boys (p<0.05) in the group of children classified as obese and not at risk according to WHtR (81.5%) than in the group formed by the normal weight and overweight children, considered at risk by WHtR (34.0%).

Figure 3. Proportion of the population, divided in categories of BMI and gender, considered as being or not at risk according to WHtR
Table 6. Comparison between WHtR and BMI after blending the normal weight children together with the overweight ones.

<table>
<thead>
<tr>
<th>BMI</th>
<th>Normal weight and overweight</th>
<th>Obese</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children not at risk</td>
<td>91.7% (n=1655)</td>
<td>1.5% (n=27)</td>
</tr>
<tr>
<td>Children at risk</td>
<td>2.8% (n=50)</td>
<td>4.0% (n=72)</td>
</tr>
</tbody>
</table>

Note: Applying the Cohen’s k, a good level of agreement was obtained (k=0.693, p<0.001). There were significant statistical differences (p<0.05) for gender (chi-square test) but not for age (One-Way ANOVA test, p>0.05) between the four groups shown in this table.
Discussion

Although it is well known that central fatness is more associated to health risks than just general weight related to height, BMI is still one of the most popular indexes used. Waist to hip ratio is the most common form for assessing the abdominal fatness. Nevertheless, cutoff values differ with gender and among various ethnic groups [28, 29]. The same happens with Waist circumference [28, 29]. Nevertheless, it has been proposed that WHtR may be a better and rapid screening tool for assessing health risks in different populations [8-11]. Moreover, it has also been reported to be useful in screening for cardiovascular risk factors among children in both Europe and Japan [10]. This may allow examiners to ignore variations in individual height that make it difficult to specify a single cutoff value for waist circumference among children. In addition, in the Bogalusa Heart Study it has been considered more associated with cardiovascular risk factors than BMI [30].

Dependency of WHtR on gender and age

No significant statistical differences were found between the WHtR of boys and girls. This supports the use of a single cutoff point, which was also suggested as a possibility in other studies, as gender did not have a significant influence on WHtR [17, 20]. However, other studies concluded that cutoff values for boys and girls may need to be developed [15, 32]. This has already been done, for example, in China [32].

The mean values of WHtR were presented for each age group, and no statistically significant differences were found. The weak correlation between age
and WHtR obtained here also supports that WHtR is age independent as shown in other studies [20, 22, 31]. However, the present results might only be related to the small range of ages considered in this sample.

Nevertheless, WHtR has also been revealed to decrease with age [18, 20, 32]. For instance, in a study of central fatness conducted on UK children and adolescents, there was a statistically significant decrease in WHtR between the ages of 5 to 16.9. They justify this as a possible divergence in the velocities of growth in height and WC with age [18].

**Children at risk**

In the present study, 6.8% of the children were considered to be at risk according to WHtR and approximately the same number of boys and girls was at risk.

Findings from other research studies lead us to speculate that these children may be at higher risk of having high levels of systolic blood pressure, diastolic blood pressure, total cholesterol, triglycerides, low-density lipoproteins and low correlation with high-density lipoprotein and, therefore have a higher probability of cardiovascular related diseases in the future [10, 21, 30, 33-35].

A comparison of changes over time in WHtR was examined in the study conducted on UK children and adolescents, mentioned before [18]. They reached the same findings as other researchers [19]: at that time, there had been a dramatic increase of this index in British children. The proportion of children at risk had increased over time with an average for all ages between 1 and 16 years from 5.0% (year 1977) to 17.0% (year 1997) in boys and from 1.5% (year 1987) to 11.7% (year 1997) in girls (P<0.01 for both). It must be mentioned that British
children of the same study referred to above were older (from 11 to 16) but still it may be of relevance to compare their results with the ones of the present study. The British children in the different age groups at risk (year 1997) ranged between 10.8% and 19.7% for boys and 7.9% and 16 % for girls and the result obtained in this study was 6.2% and 7.4% of Swedish boys and girls at risk, respectively. Considering that the prevalence of obesity and overweight children continues to increase in the UK [36-38], this might indicate that children in Sweden are at lower risk than British children [18]. In addition, a study focusing on central adiposity, which involved 9 to 15 year old Swedish children, during the years of 1998 and 1999, revealed similar WHtR values (also using 0.5 as a cutoff). Out of 557 nine-year-old children, 5% of the boys and 8% of the girls were considered as being at risk [31]. This may indicate that the situation in Sweden has been kept constant. Still, future follow-ups are needed to see whether the prevalence of Swedish children at risk is increasing or decreasing.

**Relationship of WHtR and BMI**

When classifying children according to BMI in three different categories, WHO cut off values were chosen as this may facilitate the comparison of the Swedish results in this study with the ones of other countries, also part of *WHO European Childhood growth Monitoring Surveillance Initiative*.

At present, children are typically classified as being at risk only if their BMI values are above cutoff points such as the 85th of the 95th percentile on growth charts [13]. For this reason, in the current study, the overweight and obese children were
considered to be at risk according to BMI, leading us to conclude that by using BMI as a health index, 22.1% of the current study population might be at risk of future health complications.

Even though WHtR is strongly correlated to BMI, the cutoff value used for WHtR shows us fewer children at risk than BMI does. In this study the level of agreement between these two indexes was low.

A study focusing on the relationship of BMI and WHtR to cardiovascular disease risk factors in children and adolescents concluded that these two indexes did not differ in their ability to identify children with adverse risk factors [30]. Furthermore, it has been emphasized that many of the differences between WHtR and BMI are relatively small [8]. However, if WHtR had been the only index used to get an indirect idea of children’s fatness levels we would have a much lower number of children to be concerned about, merely 6.8%.

It is possible to verify that out of the children considered at risk according to WHtR, not all of them - even though there were very few cases - would have been detected by BMI. Some researchers have concluded that WHtR can often identify people at risk within the normal range of BMI, evidence that supports the results of this study [14]. A study performed on Japanese men and women concluded that WHtR was successful at identifying overweight individuals and those of normal weight facing higher risks. This finding confirmed that not just the amount of body fat but also central fat distribution results in increased health risks in both men and women [10]. These results and the ones presented in this study may help to strengthen the idea that WHtR should be used more often as an anthropometrics index to estimate risk.
A study, using BMI as a benchmark, concluded that WHtR was an accurate index for identifying overweight and obesity in children and adolescents [17]. Therefore, by using WHtR, it is to be expected that a higher number of children classified as overweight and obese would also be considered at risk.

Within most children of the whole sample, classified as normal, most of them were indeed not at risk. Nevertheless, surprising results were found for the overweight and obese children. Only 18.3 % and 10.9% of boys and girls, respectively, classified as overweight are at risk. It would also be likely that in the obese group of children almost, if not all of them would be at risk and this too did not happen. Even though they are classified as obese, 34.4% of the boys and 14.3% of the girls did not have a WHtR equal or larger to 0.5.

The explanation for this could be that the fat distribution in these children is not mainly centered around the abdomen or, at least some of them, have a high percentage of muscle mass, as a result of histories of extensive exercise. Another reason for this big divergence may be that WHtR and BMI detect different kind of risks. For instance, it has been shown that WHtR might have a slightly stronger association with lipid and lipoprotein concentrations, whereas BMI may be slightly more associated with levels of fasting insulin and blood pressure [30, 39]. Also, even though it involved adult men and women, a study in Taiwan reported WHtR to be a better indicator for screening of cardiovascular risk factors than BMI or WC (A4). This matches the findings of several other studies [33, 40, 41]. Furthermore, in Tehranian adult men, it was revealed that WHtR was a superior predictor of type 2 diabetes than BMI [42].

When only the obese children were considered to be at risk according to BMI there
was a great increase of the overall level of agreement between the results of this index and WHtR. Therefore, the present study indicates that by using the 0.5 cutoff value, WHtR is detecting mostly the obese children and only few of those overweight.

Following the same line as the current investigation, a study that provided age and sex-specific reference values for WC and WHtR in Hong Kong Chinese children, found that a WHtR of 0.5 corresponded to the 95th percentile for boys and the 97th percentile for girls, between the ages of 14 to 18. The conclusion reached was that few of the older children would have been categorized as being at cardiovascular risk if this 0.5 single WHtR cutoff were used [32].

These differences between WHtR and BMI in assessing risk of future health problems, lead us to conclude that Ashwell’s proposed 0.5 cutoff point for predicting cardiovascular risk has yet to be tested by direct correlation with cardiovascular markers in children and may have to be lowered [23].

Contrarily to what was shown presently, it may be of interest to mention that a study conducted on Japanese adults which compared WC, BMI and WHtR’s ability to predict metabolic risk, discovered that more subjects were identified by the WHtR boundary value of 0.5 than any of the other proposed indexes of central fat distribution. This indicates that age and ethnicity may play an important role in determining the right cutoff [10].

Hence, further studies on national levels may be necessary to determine a more appropriate cutoff value for WHtR and it would be relevant to study the relationship of WHtR and BMI categorized according to the Swedish reference cutoffs.
Limitations of the present study

The group who was not included in this study may have had different characteristics from the ones that were considered and if data from these children could have been used, the results might have been different.

The participants belonged to a narrow range of ages and they may have been at different development stages. Boys and girls have different growth patterns. Therefore, this may justify many of the differences between them.

It was not always easy to measure the children’s waist circumference, especially of those who were overweight or obese. The reasons for this were that quite a few children wouldn’t keep still or didn’t feel comfortable being measured. Moreover, for the larger children it was sometimes hard to feel the lower rib and highest point of the iliac crest, thus in the worse scenario the reference point had to be changed to the belly button. These cases would then not be comparable with the ones measured using the reference point agreed upon in the protocol.

Recommendations on how to measure waist circumference differ between the Anthropometric Standardization [43], the World Health Organization and the National Institutes of Health [44]. This may lead to alterations of associations with risk factor measures and perhaps with disease risk [45-47].

A few studies to which the results in the current investigation were compared to may have used different anthropometric references, leading to greater differences between the results of those studies and the ones of the present study.

BMI is certainly not the gold standard method of assessing body fat and body
composition. Therefore, it is important that more studies comparing WHtR and BMI to more accurate methods such as Dual-energy X-ray absorptiometry (DEXA) are carried out in order to determine which one of these methods is the most efficient and thorough.
Conclusion

The results of the present study indicated that WHtR was age and gender independent in the age range of 7-9 years old.

According to WHtR, using 0.5 as a cutoff value, 6.8% of Swedish children in this sample may be at risk for cardiometabolic diseases.

There was a strong correlation between WHtR and BMI, however when it came to determining the proportion of children at risk there were noticeable differences between the two indexes. The current investigation showed that the agreement between WHtR and BMI was low. Nevertheless, if only obese children were considered to be at risk, the overall level of agreement would rise, becoming good.

Since there is evidence that WHtR and BMI may produce differing predictions for disease risks, WHtR may be a useful complementary index to BMI.

Further studies considering all age ranges, which preferably apply the gold standard method to assess body fat, are needed to determine whether the simple message, "Keep your waist circumference to less than half of your height", can be used as a possible public health strategy in a near future.
References


33. Hsieh SD, Yoshinaga H: Waist/height ratio as a simple and useful predictor of


## Annex 1

<table>
<thead>
<tr>
<th>WORLD HEALTH ORGANIZATION</th>
<th>EUROPEAN CHILDHOOD GROWTH SURVEILLANCE INITIATIVE</th>
<th>Examiner’s Record Form</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IDENTIFIKATION</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) Questionnaire code</td>
<td>EXAMINER</td>
<td></td>
</tr>
<tr>
<td>(2) Country Code</td>
<td>SWE</td>
<td></td>
</tr>
<tr>
<td>(3) Gender</td>
<td>□ Boy □ Girl</td>
<td></td>
</tr>
<tr>
<td>(4) Measurement Date</td>
<td>Day / Month / Year</td>
<td></td>
</tr>
<tr>
<td>(5) Time of Measurement</td>
<td>Hour / Minute</td>
<td></td>
</tr>
<tr>
<td>(6a) Have you had breakfast?</td>
<td>□ Yes □ No</td>
<td>(6b) Have you had lunch?</td>
</tr>
<tr>
<td>(7) Now, I would like to weigh you and measure your height. I will explain to you how I am going to do this. May I take these measurements?</td>
<td>□ Yes; child agrees to be measured (take measurements and continue with question 12)</td>
<td>□ No; child does not agree to be measured (complete question 13 and sign form)</td>
</tr>
<tr>
<td>(8) Can you tell me why you don’t want to be measured?</td>
<td>□ Child is not feeling well</td>
<td>□ Child is anxious/nervous</td>
</tr>
<tr>
<td>ANTHROPOMETRIC EXAMINATION</td>
<td></td>
<td></td>
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<tr>
<td>-----------------------------</td>
<td></td>
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<tr>
<td>(9) Body weight kg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(10) Height cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(11) Waist circumference cm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(12) Describe the clothes the child is wearing when measured (select one option only). Please remember to take off any shoes, socks or stockings as well as any heavy objects (phone, wallet, belt, etc).

- Underwear only
- Gym clothes (e.g. short and t-shirt only)
- Light Clothing (e.g. t-shirt, cotton trouser or skirt)
- Heavy Clothing (e.g. sweater and jeans)
- Other (please specify)

(13) Examiner Code

Signature ................................................ Signature .................................................................
Date ..............................................................

OBSERVATIONS BY SUPERVISOR

Data entry date ................................................. Signature .................................................................
Data checked date ............................................. Signature .................................................................