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Waist-to-height ratio, waist circumference and BMI as indicators of percentage fat mass and cardiometabolic risk factors in children aged 3–7 years

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SUMMARY

Objective: To assess whether waist-to-height-ratio (WHtR) is a better estimate of body fat percentage (BF %) and a better indicator of cardiometabolic risk factors than BMI or waist circumference (WC) in young children.

Methods: WHtR, WC and BMI were measured by trained staff according to standardized procedures. 2H2O and 2H2 18O isotope dilution were used to assess BF% in 61 children (3–7 years) from the general population, and bioelectrical impedance (Horlick equation) was used to assess BF% in 75 overweight/obese children (3–5 years). Cardiometabolic risk factors, including diastolic and systolic blood pressure, HOMA2-IR, leptin, adiponectin, triglycerides, total cholesterol, HDL- and LDL-cholesterol, TNFα and IL-6 were determined in the overweight/obese children.

Results: In the children from the general population, after adjustments for age and gender, BMI had the highest explained variance for BF% compared to WC and WHtR (R² = 0.32, 0.31 and 0.23, respectively). In the overweight/obese children, BMI and WC had a higher explained variance for BF% compared to WHtR (R² = 0.68, 0.70 and 0.50, respectively). In the overweight/obese children, WHtR, WC and BMI were all significantly positively correlated with systolic blood pressure (r = 0.23, 0.30, 0.36, respectively), HOMA2-IR (r = 0.53, 0.62, 0.63, respectively), leptin (r = 0.70, 0.77, 0.78, respectively) and triglycerides (r = 0.33, 0.36, 0.24, respectively), but not consistently with other parameters.

Conclusion: In young children, WHtR is not superior to WC or BMI in estimating BF%, nor is WHtR better correlated with cardiometabolic risk factors than WC or BMI in overweight/obese children. These data do not support the use of WHtR in young children.

1. Introduction

Various measures are used to detect obesity — defined in terms of excess body fat — and the risk of obesity-related co-morbidities. Body mass index (BMI) is the most commonly used measure, but waist circumference (WC) and waist-to-height ratio (WHtR) as measures of abdominal fat are also used. WHR may have an advantage over BMI because BMI provides no information about body fat distribution, in particular abdominal fat. Central fat distribution is associated with greater health risks than total body fat.1,2 Therefore, WHtR may be a better indicator of cardiometabolic risk factors than BMI. In adults, WHtR is found to be a better measure than BMI and WC for the prediction of obesity-related cardiometabolic risks factors.3,4 An advantage of WHtR over BMI and WC in adults is that a general cut-off value of 0.5 can be used for both men and women across many ethnicities.3,4 Moreover, the advantage of WHtR over WC is that WHtR adjusts for height. When compared to short people with the same WC, tall people have lower levels of cardiometabolic risk factors and a 30% lower prevalence of the metabolic syndrome.5

WHtR decreases from birth to the age of five from 0.69 to 0.48,5 and this decrease continues until early adolescence to 0.40–0.41.6 From then on it increases slightly to 0.42–0.43 towards the age of 18. Therefore, one cut-off value for all ages during childhood and adolescence is not feasible.6,7 In contrast to adults, it is less clear in young children whether WHtR is better than BMI or WC in

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E-mail address: e.corpeleijn@umcg.nl (E. Corpeleijn).
Table 1  
Anthropometric characteristics in the three groups of children.

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>General Population (n = 30, 40% boys)</th>
<th>General Population (n = 31, 56% boys)</th>
<th>Overweight/obese population (n = 75, 28% boys)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>3–4 years</td>
<td>27.3</td>
<td>3.3</td>
<td>29.2</td>
</tr>
<tr>
<td>6–7 years</td>
<td>32.3</td>
<td>3.3</td>
<td>35.2</td>
</tr>
</tbody>
</table>

Table 2  
Associations of WHtR, WC and BMI with body fat percentage.

<table>
<thead>
<tr>
<th>Body fat percentage</th>
<th>3–4 years of age</th>
<th>6–7 years of age</th>
<th>3–4 and 6–7 years of age</th>
<th>3–5 years of age</th>
</tr>
</thead>
<tbody>
<tr>
<td>General population</td>
<td>General population</td>
<td>Overweight/obese population</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>WHtR</strong></td>
<td><strong>r</strong></td>
<td><strong>R^2</strong></td>
<td><strong>r</strong></td>
<td><strong>R^2</strong></td>
</tr>
<tr>
<td>Crude</td>
<td>0.12</td>
<td>0.35</td>
<td>0.11</td>
<td>0.33</td>
</tr>
<tr>
<td>+Gender</td>
<td>0.24</td>
<td>0.29**</td>
<td>0.08</td>
<td>0.13</td>
</tr>
<tr>
<td>+Gender, age</td>
<td>0.40**</td>
<td>0.30*</td>
<td>0.30</td>
<td>0.30**</td>
</tr>
<tr>
<td><strong>WC</strong></td>
<td><strong>r</strong></td>
<td><strong>R^2</strong></td>
<td><strong>r</strong></td>
<td><strong>R^2</strong></td>
</tr>
<tr>
<td>Crude</td>
<td>0.23*</td>
<td>0.35</td>
<td>0.11</td>
<td>0.33</td>
</tr>
<tr>
<td>+Gender</td>
<td>0.34**</td>
<td>0.49***</td>
<td>0.17</td>
<td>0.22</td>
</tr>
<tr>
<td>+Gender, age</td>
<td>0.35**</td>
<td>0.51**</td>
<td>0.17</td>
<td>0.22</td>
</tr>
<tr>
<td><strong>BMI</strong></td>
<td><strong>r</strong></td>
<td><strong>R^2</strong></td>
<td><strong>r</strong></td>
<td><strong>R^2</strong></td>
</tr>
<tr>
<td>Crude</td>
<td>0.10</td>
<td>0.12</td>
<td>0.17</td>
<td>0.22</td>
</tr>
<tr>
<td>+Gender</td>
<td>0.22</td>
<td>0.20**</td>
<td>1.87</td>
<td>0.79</td>
</tr>
<tr>
<td>+Gender, age</td>
<td>0.35**</td>
<td>0.68***</td>
<td>2.14</td>
<td>1.75</td>
</tr>
</tbody>
</table>

BFI, body fat percentage; BMI, body mass index; WC, waist circumference; WHtR, waist-to-height ratio.

Hp < 0.05; *p < 0.01; **p < 0.001.

Table 3  
Associations of WHtR, WC and BMI with cardiometabolic risk factors.

<table>
<thead>
<tr>
<th>Cardiometabolic risk factor</th>
<th>3–4 years of age</th>
<th>6–7 years of age</th>
<th>3–4 and 6–7 years of age</th>
</tr>
</thead>
<tbody>
<tr>
<td>General population</td>
<td>General population</td>
<td>Overweight/obese population</td>
<td></td>
</tr>
<tr>
<td><strong>WHtR</strong></td>
<td><strong>r</strong></td>
<td><strong>R^2</strong></td>
<td><strong>r</strong></td>
</tr>
<tr>
<td>Crude</td>
<td>0.12</td>
<td>0.35</td>
<td>0.11</td>
</tr>
<tr>
<td>+Gender</td>
<td>0.24</td>
<td>0.29**</td>
<td>0.08</td>
</tr>
<tr>
<td>+Gender, age</td>
<td>0.40**</td>
<td>0.30*</td>
<td>0.30</td>
</tr>
<tr>
<td><strong>WC</strong></td>
<td><strong>r</strong></td>
<td><strong>R^2</strong></td>
<td><strong>r</strong></td>
</tr>
<tr>
<td>Crude</td>
<td>0.23*</td>
<td>0.35</td>
<td>0.11</td>
</tr>
<tr>
<td>+Gender</td>
<td>0.34**</td>
<td>0.49***</td>
<td>0.17</td>
</tr>
<tr>
<td>+Gender, age</td>
<td>0.35**</td>
<td>0.51**</td>
<td>0.17</td>
</tr>
<tr>
<td><strong>BMI</strong></td>
<td><strong>r</strong></td>
<td><strong>R^2</strong></td>
<td><strong>r</strong></td>
</tr>
<tr>
<td>Crude</td>
<td>0.10</td>
<td>0.12</td>
<td>0.17</td>
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<tr>
<td>+Gender</td>
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<td>0.20**</td>
<td>1.87</td>
</tr>
<tr>
<td>+Gender, age</td>
<td>0.35**</td>
<td>0.68***</td>
<td>2.14</td>
</tr>
</tbody>
</table>

BMI, body mass index; WC, waist circumference; WHtR, waist-to-height ratio.

Hp < 0.05; *p < 0.01; **p < 0.001.
association was found with BMI or WC. This inverse association was also found in a previous review, while no association was found in children younger than 6 years.15 Whitrow et al. assessed whether WHtR is a better indicator than BMI of SBP in children, 3.5 years of age.17 Campagnolo et al. assessed the accuracy of WHtR, WC and BMI in identifying children (3–4 years of age) with multiple risk factors for cardiovascular disease. No correlations between the anthropometric measures and the separate cardiovascular risk factors were found.10

We found that apart from HDL-cholesterol none of the cardiovascular risk factors were better correlated with WHtR than with BMI or WC (i.e. SBP, HOMA2-IR, leptin and triglycerides). This is in accordance with most previous studies in children aged 4–17 years, based on a review by Browning et al.1 For HDL-cholesterol we found a significant inverse association with WHtR, while no association was found with BMI or WC. This inverse association was also found in a previous review, while no association was found in young children.15 The lack of association between total cholesterol and IL-6 with WHtR has also been found in previous studies.15 The positive association with triglycerides is consistent with studies in older children, but was not found in young children.15 The absence of an association of WHtR with DBP, adiponectin, LDL-cholesterol and TNFα in young children has not been published before.

A major strength of our study is that the sample was composed of young children of 3–7 years of age. In addition, relationships were studied in overweight/obese children. Studies analysing these relationships in young children are limited and we found no studies that analysed these in overweight/obese children at this young age, despite these children being the target population for intervention programmes. The low number of children in the general population groups is a limitation of our study. Although for diagnosis purposes, the cross-sectional design of the study is adequate, the drawback is that it gives no information about the ability of the proxy measures to predict cardiometabolic risk factors later in life. For diagnosis of excess adiposity, cross-sectional data are sufficient, but it would be...
interesting and very relevant to relate the adiposity measures to future health outcomes.

In conclusion, in young children, either from the general population or overweight/obese, WHtR was not superior to WC or BMI in estimating BF%, nor was WHR better correlated with cardio metabolic risk factors than WC or BMI in overweight/obese children. These data do not support the use of WHtR in young children.

Conflict of interest

The authors declare there are no competing financial interests in relation to the work described.

References


