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Analysis of Body Composition of Children Aged 13 with Normal Body Mass Index and Waist Circumference Above the 90th Percentile

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The present study was aimed at analysing body composition in children aged 13 who, while showing normal BMI, had waist circumference above the 90th percentile, indicative of visceral fat accumulation. The study showed the situation to be related both to the elevated percentage of adipose tissue in the body and to reduced percentages of fat-free body mass and water. The girls examined showed their body fat percentage to vary within 19.5–32.7% (mean 26.9±3.8%) against the reference level of 18–25%; the girls' fat-free body mass ranged within 67.3–80.5% (mean 71.3±3.8%) against the reference level of 72–82%; the percentage of water in their body ranged within 50.9–60.8% (mean 55.3±2.9%) against the reference level of 57–62%. The boys examined showed their body fat percentage to vary within 20.5–35.5% (mean 25.3±6.4%) against the reference level of 12–18%; their fat-free body mass to range within 64.7–89.5% (mean 74.7±6.4%) against the reference level of 82–88%; and the percentage of water in their body to vary within 48.3–66.9% (mean 55.8±4.8%) against the reference level of 61–66%.

As shown by the results, the normal BMI cannot be the only criterion with which to assess the nutritional status of a child, particularly at puberty.

INTRODUCTION

As shown by numerous epidemiological studies, accumulation of adipose tissue by obese individuals carries an associated risk of the metabolic syndrome with all its consequences, *i.e.*, hyperglycaemia, insulin resistance, lipid metabolism disorders, and hypertension [Bednarek-Tupikowska *et al*., 2007]. Similar effects may be caused by age-dependent increase in the content of fat in the body, including the visceral (intra-abdominal) fat [Beaufrère & Morio, 2000]. Increasingly common are also reports indicating that similar effects may be caused by visceral adipose tissue accumulation by children and adolescents [Bryl *et al*., 2006; Hirschler *et al*., 2005].

The problem of obesity and associated metabolic and health disorders is relatively well studied. On the other hand, studies on healthy, non-obese individuals whose body weight is normal but who carry an excessive amount of abdominal fat (the so-called metabolically obese normal-weight, MONW) have been fairly scarce. Still less known is the problem in children.

According to the recent definition developed by the International Diabetological Federation, abdominal obesity is the major and indispensable condition for diagnosing the metabolic syndrome [The IDF Consensus, 2007].

Therefore, it was deemed important that the educational programme "How to be healthy, wise, and beautiful" targeting upper secondary school students pays attention to those children whose body weight is normal, but their WC exceeds the 90th percentile (WC≥90).

The study was aimed at analysing body composition of children aged 13 who – while showing normal BMI – have waist circumference ≥90th percentile.

SUBJECTS AND METHODS

The study was conducted in October of 2007 and 2008 amongst 904 first year students of 44 lower secondary and 11 schools in Szczecin selected at random (431 girls and 473 boys). The choice of children aged 13±0.4 was motivated by the fact that this is the age at which changes leading to insulin resistance and cardiovascular disorders can be detected for the first time [Skowrońska *et al*., 2005; Bryl *et al*., 2006]. The study was approved by the Local Ethical Commission (consent no. BN-001/93/07).

To assess a child's nutritional status, anthropometric measurements (body weight, height, and waist circumference) were taken (at the school nurse's room). The children, shoeless and in light clothes, were weighed (exact to 0.1 kg) on a legalised and standardised medical scales. Body height was measured (exact to 0.5 cm) with a stadiometre mounted on the scales, in the Frankfurt plane (the corner of the eyes horizontal to the middle of the ear). The waist circumference was

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measured (exact to 1 cm), with a measuring tape, at the navel level, the child holding his/her breath briefly when the measurement was being taken.

The data obtained served to calculate: the Body Mass Index (BMI), Waist Circumference (WC) and Waist to Hip Ratio (WHtR).

BMI values were referred to the appropriate (in terms of gender and age) percentile charts developed by the Institute of Mother and Child [Palczewska & Szilágyi-Pągowska, 2002], WC and WHtR values being referred to the Łódź children percentile charts [Nawarycz & Ostrowska-Nawarycz, 2007a, b].

WC and WHtR ≥90th percentile were regarded as criteria of visceral fat tissue accumulation.

A total of 224 children (25% of the population examined) showed WC≥90. Upon parental consent, all the children were asked to have their body composition measured by electric bioimpedance. Of the 65 children with normal BMI, 50 (28 girls and 22 boys) agreed to be measured.

The measurements, by means of Bodystat®1500MDD with Body Manager software adjusted for the analysis of children body composition, *i.e.* using regression equations for body composition of children at the age of 11–19 years [Houtkooper *et al*., 1992], were taken in school nurse's room, following all the recommendations regarding the correct measuring procedure. As the children were required to refrain from eating prior to the measurement, once measured, each child received a nutritious breakfast.

The data obtained were subject to statistical treatment involving the use of the Microsoft Excel 2003.

RESULTS

The general characteristics of the surveyed group of children was presented in Tables 1 and 2. Data contained therein demonstrate that, despite great individual differences, the mean values of BMI, WC and WHtR parameters fitted within recommended standard values both in the case of girls and boys (Table 1).

In the surveyed group, children with the normal BMI values constituted 29% (65 children, including 43 girls – 66% and 22 boys – 34%). In the case of 71% subjects (159 children, including 84 girls – 53% and 75 boys – 47%) the BMI values were indicative of obesity or overweight (Table 2).

TABLE 2. Percentage of 13-year old children depending of the Waist Circumference and Waist-to-Height Ratio indicator value (n = 904).

Range of percentile	Waist Circumference				Waist-to-Height Ratio			
	Girls (n=431)		Boys (n=473)		Girls (n=431)		Boys (n=473)	
	n	%	n	%	n	%	n	%
≤5 percentile	7	1.6	9	1.9	5	1.2	8	1.7
10–75 percentile	297	68.9	367	77.6	307	71.2	375	79.3
≥90 percentile	127	29.5	97	20.5	119	27.6	90	19.0

An analysis of the diagnostic indices (BMI, WC, and WHtR) showed that, despite normal BMI (BMI value in 28% of the subjects ranged from 18.8 to 19.5, and in 72% of the subjects – from 20.3 to 21.7), even the lowest WC in the girls examined was higher than the maximum reference value (Table 3). On the other hand, not all the girls showed WHtR higher than normal; however, the mean WHtR did exceed the upper reference limit.

A similar pattern was observed in the boys examined (BMI value in 33.5% of the subjects ranged from 20.2 to 21.5, and in 66.5% of the subjects – from 21.7 to 22.8): the lowest WC was also higher than the upper reference limit. Similarly to the girls, not all the boys showed WHtR higher than normal, but the mean WHtR exceeded the upper reference limit (Table 3).

An analysis of body composition of the girls examined showed even the lowest body fat content to be higher than the upper reference limit (Table 4). The high fat contents were accompanied by reduced fat-free body mass; although the mean values stayed within the reference range, the actual values were often below the lower reference level, similarly to the body water content.

A similar pattern was found in the boys examined (Table 4), even the lowest body fat percentage was higher than the upper reference limit. Reduced fat-free body mass and water content were prevalent as well.

DISCUSSION

Puberty is a period critical for the total body fat accumulation and distribution of fat tissue in the body. It is generally assumed that WHtR in girls at puberty systematically

TABLE 1. Values of anthropometric measurements, and Body Mass Index, Waist Circumference, and Waist-to-Height Ratio indicators in 13-year old girls (n=431) and boys (n=473).

Sex \ Attributes and Indicators		Total body mass (kg)	Body height (m)	Body Mass Index (kg/m^2)	Waist Circumference (cm)	Waist-to-Height Ratio (cm/cm)
Girls	Range	33.0–94.5	1.40–1.82	14.0–34.7	53.0–106.5	0.361–0.648
	x±SD	52.3±10.7	1.60±0.12	20.2±3.2	72.0±8.2	0.449±0.050
	Reference level	38.0–59.9	1.50–1.66	15.9–21.8	58.2–75.5	0.370–0.473
Boys	Range	29.5–109.4	1.15–1.86	13.8–37.7	55.0–114.0	0.344–0.726
	x±SD	51.4±11.1	1.62±0.16	20.4±3.4	74.0±9.7	0.455±0.017
	Reference level	36.8–64.9	1.49–1.69	15.9–22.9	59.8–80.8	0.380–0.495

TABLE 3. Values of anthropometric measurements and Body Mass Index, Waist Circumference, and Waist-to-Height Ratio indicators in 13-year old girls (n=28) and boys (n=22) with WC≥90c.

Sex \ Attributes and Indicators		Total body mass (kg)	Body height (m)	Body Mass Index (kg/m^2)	Waist Circumference (cm)	Waist-to-Height Ratio (cm/cm)
Girls	Range	46.2–68.0	1.53–1.82	18.8–21.7	76–91	0.430–0.520
	x±SD	55.3±4.7	1.59±0.3	20.5±0.9	79.1±3.9	0.479±0.02
	Reference level	38.0–59.9	1.50–1.66	15.9–21.8	58.2–75.5	0.370–0.473
Boys	Range	48.0–73.5	1.52–1.81	20.2–22.8	81.0–88.5	0.450–0.575
	x±SD	60.1±6.3	1.65±0.8	22.1±0.8	81.8±2.0	0.498±0.03
	Reference level	36.8–64.9	1.49–1.69	15.9–22.9	59.8–80.8	0.380–0.495

TABLE 4. Body mass composition in 13-year old girls (n=28) and boys (n=22) with WC≥90c.

Sex \ Attributes and Indicators		Total body fat (kg)	Total body fat (%)	Lean body weight (kg)	Lean body weight (%)	Dry lean weight (kg)	Body water (L)	Body water (%)
Girls	Range	11.4–19.1	19.5–32.7	33.7–49.5	67.3–80.5	8.1–12.1	25.4–37.4	50.9–60.8
	x±SD	12.9±2.5	26.9±3.8	40.6±4.0	73.1±3.8	9.9±1.0	30.7±3.0	55.3±2.9
	Reference level		18–25		72–82			57–62
Boys	Range	7.7–22.5	20.5–35.5	34.6–65.8	64.7–89.5	8.8–16.6	25.8–49.2	48.3–66.9
	x±SD	15.1±3.7	25.3±6.4	45.9±7.3	74.7±6.4	11.3±1.8	33.7±5.5	55.8±4.8
	Reference level		12–18		82–88			61–66

decreases, indicating a higher body height increase rate relative to that of the waist circumference. A similar trend in boys occurs only at the age of 13–14.

Considering that the study involved children with normal body weight but with a too large waist circumference, it is understandable that the pattern may be different in those children. As few as 24% of the girls examined showed WHtR below the upper reference level. Similarly, as few as 24% of the boys (at the age when the pattern described above holds true) had WHtR lower than the upper reference limit.

The universal and most commonly used overweight and obesity criteria, particularly those pertaining to abdominal obesity in developing humans, are a subject of wide debate. At present, the commonly accepted criteria, for both adults and children/adolescents, include WC and WHtR as indicators of visceral fat location. It is contended that WC and WHtR in children are better indicators of circulatory system disorders than BMI [Taylor *et al*., 2000]. Hirschler *et al*. [2005] demonstrated that children and adolescents with abdominal obesity indicated by waist circumference (WC) carry a higher risk of cardiovascular disease and type 2 diabetes due to frequent insulin resistance.

Thus, considering the results obtained in this study, it may be presumed that – despite the lack of general obesity – the children examined may be threatened by metabolic disorders. This is because central accumulation of adipose tissue is associated, also in children and adolescents, with unfavourable lipid profile and lipoprotein concentration, higher blood pressure, and higher left cardiac chamber mass [Goran & Gower, 1999]. The WC values higher than the 90th percentile are significantly correlated with blood lipid and lipoprotein concentrations and are associated with a higher risk of cardiovascular diseases, compared to the situation in children with WC below the 90th percentile [Moreno *et al*., 2002]. In addition, during puberty, the peripheral tissues become less sensitive to insulin, which is associated with higher insulin and glucose concentration prior to eating. Although insulin resistance at that time seems to be selective with respect to glucose metabolism and does not apply to protein metabolism, it does contribute to the increased anabolic effect of insulin and growth hormone [Am. Diab. Assoc., 2000], thus exacerbating the disorders that are already present.

An analysis of the results allowed to conclude that, despite normal body weight and BMI, accumulation of the visceral adipose tissue in the children examined was associated with changed body composition, not only with respect to the fat content, but also to fat-free body mass and water content.

An analysis of body composition of the girls examined showed the fat content, important for the evaluation of metabolic disorder risk, was in all of the much higher than that suggested by their BMI values. Even the girls with BMI within 18.8–19.5 (28% of the individuals examined) showed body fat contents ranging from 23.3 to 32.7% of the body weight.

Fat-free body mass, a good indicator of physiological and biochemical functions of the body and of total muscle tissue content, was in 35% of the girls below the lower reference level. It was accompanied with the body water content lower than the reference range of 57–62%. As few as 14% of the girls examined had their body water content consistent with the reference range, the remaining 86% of the girls showing lower or higher water deficiency.

The body fat content in boys was also markedly higher than that suggested by the BMI values. As few as 3.5% of the boys examined had their body fat content below the lower reference level, 3.5% of the boys showing the fact content consistent with the reference. The body fat content in the remaining

97% of the boys accounted for 22–35.5% of the body weight (against the reference range of 12–18%).

The fat-free body mass was below the lower reference limit in 97% of the boys examined. It was accompanied by the body water content lower than the recommended range of 61–66%. Similarly to the fat-free body mass, as few as 7% of the boys examined (the same boys who showed normal fat-free body mass and too low or normal fat content) showed their body water content to be consistent with the reference level. The remaining 93% of the boys revealed higher or lower water deficiency.

An analysis of body composition of the children examined showed the values of individual metrics to be very similar, despite the gender factor. In view of the fact that the reference levels differentiate between girls and boys aged 13 years, it may be concluded that the boys showed less favourable levels of body fat content, fat-free body mass, and body water content. Whereas adverse effects of excessive body fat, particularly the visceral adipose tissue, are well known, irregularities of other parameters indicative of the health status, *i.e.*, the fat-free body mass and water content, have not received as much attention. Particularly the water content deficiency raises serious concern. Owing to its special physical and chemical properties, water is considered one of the major body components. Water deficiency up to 10% is not signalled by thirst, but gives rise to, *i.a.*, the feeling of permanent fatigue, not alleviated by rest, which may cause apathy of a child and his/her unwillingness to engage in physical activities. The urea excretion becomes reduced, whereby excretion of metabolic products is reduced as well, which is known to contribute to urolithiasis, also in children [Al Zahrani *et al*., 2000].

When searching for causes of the situation described here, one may pinpoint the diet as the primary culprit. However, earlier studies [Goluch-Koniuszy *et al*., 2009] showed the diet of the children examined, particularly those with WC≥90th percentile was not significantly different in terms of the diet's energy content, lower – particularly in girls – than the recommended level, and too low consumption of fat, dietary fibre, calcium, magnesium, and vitamin E. In addition, all the children examined consumed too little fruits and vegetables. However, when comparing the diets of the children with WC≥90th percentile which differed in their BMI, those children having normal BMI consumed significantly more total protein, calcium, vitamins A and B, and water [Goluch-Koniuszy & Radziszewska, 2009]. In addition, those children ate more sweets, which can be explained by a higher parental acceptance of such snacks consumed by children with normal body weight.

Therefore, the problem may be more complex, particularly with regard to the girls who, as shown by results of polls, had already been "on diet" at least once, the slimming diet usually involving rejection of cereals, potatoes, and fat. This is important because the weight loss accompanying an inappropriate diet leads not only to the accumulation of energy substrates [Słonka, 1998], but primarily to the reduction of fat-free body mass and loss of water [Poskitt, 1995]. The way the children spend their free time and their diet composition sum up to yield increased accumulation of adipose tissue without excessive increase in body weight and/or BMI.

Considering the type of disorders caused by the visceral adipose tissue accumulation, it seems that improved dietary habits offer a possibility to reverse the inappropriate proportions in the children's body composition. A corrected diet should involve a higher consumption of vegetables and fruits, coarse grits, pulses, fatty fish, and appropriate amounts and types of fats, *i.e.*, diet components which are not only higher in basic nutrients, but are also replete in vitamins, minerals, and bioactive compounds participating in metabolism, including that of lipids. It is also important to increase the liquid uptake by the children, including water. As shown by Friedrich [2007], a correct diet – even in menopausal women – not only favours the loss of visceral adipose tissue and body weight, but also allows to maintain or increase the fat-free body mass and water. The latter is associated with the role of potassium, occurring at high concentrations in vegetables and fruits, in the water-mineral transformations in the body [Morris *et al*., 2006].

As shown by the literature, the age of 13 is the first, early moment when metabolic disorders can be diagnosed. Early diagnosis of the metabolic disorder during puberty may be a chance of preventing, *via* prophylaxis, the associated metabolic problems [Iwańska *et al*., 2005]. Therefore, the children participating in the educational programme "How to be healthy, wise, and beautiful" were provided education focusing on appropriate nutrition and took part in nutrition workshops. All the children whose metrics indicated deviations from the reference levels were offered individual counselling and diet correction. As few as 13% of the 224 dysfunctional children accepted the offer; however, none of those children belonged to the group with normal body weight and BMI but with WC above the 90th percentile.

CONCLUSIONS

1. The normal BMI values were found not to determine the proper body composition in the surveyed children.
2. In the case of all girls and in 93% of the boys, the value of WC parameter exceeding the 90th percentile was linked with an increased percentage of adipose tissue, which in most cases was accompanied by a diminished content of water and lean body mass.
3. The observed changes were more intensified in the case of boys.
4. Generally, the WC values exceeding the 90th percentile were observed more often in the girls, irrespective of their BMI values.

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