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# ASSESSMENT OF BODY CONSTITUTION IN CHILDREN FROM BRATISLAVA (SLOVAKIA) AT EARLY SCHOOL AGE

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**Abstract:** The aim of the study was to verify the reliability of the body mass index (BMI) criteria in identifying normal weight and obesity with respect to gender. Anthropometric parameters (AP) – body height, weight, waist circumference, biceps, triceps, subscapular and suprailiac skinfolds were measured by standard techniques in 1,582 healthy children aged 6 –10 years living in Bratislava. Adiposity was evaluated by BMI using International Obesity Task Force (IOTF) definitions, waist height ratio (WHtR) and fat mass index (FMI). Combination of all three criteria adjusted for gender and age was used for the specification of body constitution. The mutual compliance of these criteria for identifying obesity was evaluated by chí-square. In non-obese boys (79%) and girls (81%), increased FMI>97$^{th}$ percentile (P) in 8.5% and 9.9% respectively was found. In all obese (6.2% boys and 4.2% girls), FMI and WHtR congruent to obesity. In only 2.2% of overweight boys and 1.2% of girls, normal fat content was confirmed. BMI classified according to IOTF remain a basic tool for the identification of obesity. However, the level of body fatness determined by WHtR and skinfold thicknesses may substantially contribute to recognizing a health risk associated with obesity in children.

**Key words:** physical anthropology, children, body mass index, waist-to-height ratio, fat mass index, Central Europe

## Introduction

Body mass index (BMI) as an indirect marker of metabolic risks in adults is widely used also in children with cut-offs adjusted for gender and age recommended by World Health Organization (WHO; de Onis et al. 2007), International Obesity Task Force (IOTF; Cole and Lobstein 2012), Center for Disease Control and Prevention (CDC; Kuczmarski et al. 2000). Many countries including Slovakia have their own nation specific references (Regecová et al. 2015). Moreover, BMI does not fully reflect body fat content and may be less powerful as a predictor of the health risk of any kind. The limitations of BMI as well as suggestions for their overcoming are long before and frequently discussed (Rolland-Cachera et al. 1982, Pietrobelli et al. 1998, Lean, Han and Deurenberg 1996, Silva et al. 2013). However, accurate laboratory methods for the analysis of total and abdominal fat, like dual-energy X-ray absorptiometry, magnetic resonance imaging or underwater weighing are not appropriate for screening purposes (Wells and Fewtrell 2006, 2008). For this reason, waist circumference (WC), waist-to-height ratio (WHtR) and skinfold thicknesses (ST) as the indirect measures still have their place in the assessment of the adiposity in children.

There are no reference data for these parameters for Slovak population, so we used as standards the data of international study on Identification and prevention of Dietary- and lifestyle-induced health Effects in Children and infantS (IDEFICS) processed on the data of children up to age of 10.9 years from eight European countries (Nagy et al. 2014). Based on the previous findings (Keys et al. 1972, Deurenberg, Yap and van Staveren 1998, Nutall 2015), our hypothesis assumes disparities between the classification of normal weight and obesity by BMI, WHtR and ST. The aim of this study was to detect to what extend differ or agree on the results of these three methods at the age range of 6 to 10 years.

**Methods**

A cross-sectional study was conducted on a sample of 1,582 healthy children (773 boys) aged 6–10 years living in Bratislava. All measurements were performed by trained health care workers using the standardized technique (Tanner, Hiernaux and Jarman 1969). Waist circumference (WC) was measured at the mid-point between the lowest rib and the top of the iliac crest on the naked skin at the end of a normal expiration. BMI was calculated as weight in kilograms (kg) divided by height in meters squared, WHtR as WC (cm) divided by height (cm). Z-scores were determined using the program LMSgrowth 2.77, a Microsoft Excel add-in (Pan and Cole 2002 – 2012) where recently parameters of LMS for height, weight, and BMI also for Slovak population were incorporated (Regecová 2015). Biceps, triceps subscapular and suprailiac ST were taken by Harpenden caliper (Somet). Fat percentage and fat mass index (FMI) were calculated according to Slaughter equations (1988) and IDEFICS study (Nagy et al. 2014, 2016). Medians and empirical $97^{th}$ P of WHtR and FMI in non-overweight children were compared with respective values of IDEFICS standards. For BMI classification IOTF standards were used (Cole and Lobstein 2012).

Types of obesity were determined by BMI, WHtR, and FMI. The control group (CG) was represented by normal BMI by IOTF (Cole and Lobstein 2012), WHtR and FMI $<97^{th}$ P (Nagy et al. 2014, 2016). Types of obesity were defined by a combination of the following criteria: 1. Overweight (OW): BMI ≥stage 1 <stage 2, WHtR ≥ and/or FMI ≥ $97^{th}$ P, 2. Fake obesity (FO): BMI ≥ stage 1 < stage 2, WHtR and FMI < $97^{th}$ P, 3. Hidden obesity (HO): normal BMI and WHtR and FMI ≥ $97^{th}$ P, 4. Abdominal obesity (AO): normal BMI and FMI and WHtR ≥ $97^{th}$ P, 5. Obesity: BMI ≥ stage 2, WHtR and FMI ≥ $97^{th}$ P. The mutual compliance of these criteria for identifying obesity as well as the gender differences between obesity categories were evaluated by chi-squared test. Mean and median values of AP were compared by ANOVA, in case of not normal distribution the Kruskal-Wallis variant was used.

**Results**

Mean values of body height, weight, waist circumference, and BMI are presented in Table 1 and 2. Z-scores of children in Bratislava related to Slovak standards were positive, higher in boys and increased with age, ranging from 0.07 (body height in 6 y boys) to 0.58 (body weight in 10-year-old boys). Prevalence of overweight and obesity was highest at the age 8–9 years. Significant gender differences in body weight ($p=0.01$), BMI ($p=0.02$), and WC ($p=0.009$) were confirmed only in the oldest age group.

Values of skinfold thicknesses and FMI increased with age and were significantly higher ($p<0.001$) in girls throughout all age range (Table 3, 4). Medians of the sum of four ST and values of $97^{th}$ P (empirical) in non-obese children were similar to IDEFICS standards, except the youngest age group, was higher by 3.6 to 8.6 mm. FMI had shown the greatest consistency with IDEFICS standards in 7- to 8-year-old boys. Higher proportions of subjects exceeding the level of $97^{th}$ P (in spite of normal BMI), were found in the category of 9–10 years, especially in girls (Table 4). All in all, FMI was above these cut-offs in 7.3% boys and 9.9% girls instead of expected 3%. In contrast with fat mass, WHtR did not differ from IDEFICS standards, without significant gender and age-related differences.

Table 1: Mean values, standard deviations, and z-score by Slovak standards of body height, weight, waist circumference and body mass index in boys. Percentages of overweight and obesity were based on IOTF definitions.

| Age | Height (cm) | | | Weight (kg) | | | Waist circumference (cm) | | | Body mass index (kg/m$^2$) | | | Percentage (IOTF) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **years** | **Mean** | **SD** | **Z** | **Mean** | **SD** | **Z** | **Mean** | **SD** | **Z** | **Mean** | **SD** | **Z** | **OW** | **OB** |
| **6** | 121.7 | 5.6 | 0.07 | 23.8 | 4.4 | 0.14 | 55.7 | 5.0 | -0.05 | 16.0 | 2.2 | 0.13 | 8.1 | 4.3 |
| **7** | 128.4 | 6.0 | 0.24 | 27.9 | 5.6 | 0.47 | 59.4 | 7.0 | 0.29 | 16.8 | 2.6 | 0.37 | 13.5 | 9.0 |
| **8** | 135.6 | 6.3 | 0.45 | 32.2 | 7.6 | 0.53 | 62.8 | 9.1 | 0.43 | 17.4 | 3.1 | 0.43 | 20.0 | 6.2 |
| **9** | 140.6 | 6.0 | 0.38 | 36.0 | 8.6 | 0.52 | 65.5 | 9.6 | 0.47 | 18.0 | 3.2 | 0.47 | 16.5 | 8.7 |
| **10** | 146.5 | 7.0 | 0.46 | **40.2** | 8.7 | **0.58** | **68.1** | 9.2 | **0.57** | **18.6** | 3.1 | **0.54** | 18.9 | 5.5 |
| **All** | 132.6 | 11.0 | 0.28 | 30.7 | 9.1 | 0.41 | 61.3 | 9.0 | 0.29 | 17.2 | 3.0 | 0.35 | 14.3 | 6.5 |

Explanations: SD – standard deviations, Z – z-score, OW– overweight, OB – obese. Bold figures indicate significant higher values of AP as compared with girls displayed in Table 2.

Table 2: Mean values, standard deviations, and z-score by Slovak standards of body height, weight, waist circumference and body mass index in girls. Percentages of overweight and obesity were based on IOTF definitions.

| Age | Height (cm) | | | Weight (kg) | | | Waist circumference (cm) | | | Body mass index (kg/m$^2$) | | | Percentage (IOTF) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **years** | **Mean** | **SD** | **Z** | **Mean** | **SD** | **Z** | **Mean** | **SD** | **Z** | **Mean** | **SD** | **Z** | **OW** | **OB** |
| **6** | 121.2 | 5.1 | 0.16 | 23.3 | 4.3 | 0.23 | 54.7 | 6.0 | -0.10 | 15.8 | 2.1 | 0.14 | 7.8 | 3.9 |
| **7** | 128.0 | 5.9 | 0.29 | 27.0 | 5.1 | 0.39 | 58.1 | 5.9 | 0.30 | 16.3 | 2.1 | 0.30 | 17.9 | 1.9 |
| **8** | 134.6 | 6.5 | 0.48 | 31.1 | 6.4 | 0.55 | 61.3 | 8.0 | 0.47 | 17.1 | 2.7 | 0.41 | 21.9 | 4.9 |
| **9** | 139.7 | 6.6 | 0.40 | 34.6 | 7.9 | 0.49 | 63.7 | 8.9 | 0.51 | 17.6 | 3.0 | 0.39 | 15.7 | 6.5 |
| **10** | 145.4 | 7.7 | 0.22 | 38.1 | 9.1 | 0.29 | 65.7 | 8.8 | 0.46 | 17.9 | 3.2 | 0.23 | 15.4 | 4.2 |
| **All** | 132.3 | 10.9 | 0.29 | 30.0 | 8.6 | 0.37 | 60.0 | 8.5 | 0.28 | 16.8 | 2.7 | 0.28 | 14.8 | 4.2 |

Explanations: SD – standard deviations, Z – z-score, OW – overweight, OB – obese

Table 3: Medians and 97$^{th}$ percentiles for the sum of biceps, triceps, subscapular and suprailiac skinfolds, and fat mass index in normal weight boys.

| Age | Sum of 4 skinfolds (mm) | | | | Waist-to-height ratio | | | | Fat mass index | | | | >97$^{th}$ P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **years** | **Median** | **DIF** | **97$^{th}$ P** | **DIF** | **Median** | **DIF** | **97$^{th}$ P** | **DIF** | **Median** | **DIF** | **97$^{th}$ P** | **DIF** | **%** |
| **6** | 27.4 | 3.6 | 46.0 | 8.6 | 0.45 | 0.01 | 0.50 | 0.01 | 2.31 | 0.11 | 3.82 | 0.32 | 8.8 |
| **7** | 23.5 | -1.1 | 38.6 | 0.1 | 0.44 | 0.01 | 0.49 | 0.00 | 2.15 | -0.05 | 3.72 | -0.18 | 4.2 |
| **8** | 25.0 | 0.4 | 42.2 | 0.1 | 0.43 | 0.00 | 0.49 | 0.01 | 2.39 | -0.01 | 4.14 | -0.26 | 6.2 |
| **9** | 26.3 | -0.7 | 55.4 | 5.4 | 0.44 | 0.01 | 0.51 | 0.03 | 2.61 | 0.01 | 6.32 | 1.42 | 10.5 |
| **10** | 27.5 | -1.3 | 52.6 | -6.3 | 0.43 | 0.01 | 0.51 | 0.03 | 3.13 | 0.23 | 6.22 | 0.82 | 8.3 |
| **All** | 26.0 | -0.2 | 47.2 | 2.0 | 0.44 | 0.01 | 0.50 | 0.02 | 2.43 | 0.06 | 4.90 | 0.42 | 7.3 |

Explanations: DIF – differences between respective parameters and IDEFICS standards,
>97$^{th}$ P – the prevalence of boys with FMI higher than 97$^{th}$ percentile expressed as a percentage.

Table 4: Medians and 97th percentiles for the sum of biceps, triceps, subscapular and suprailiac skinfolds, and fat mass index in normal weight girls.

| Age years | Sum of 4 skinfolds (mm) | | | | Waist-to-height ratio | | | | Fat mass index | | | | >97th P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Median** | **DIF** | **97th P** | **DIF** | **Median** | **DIF** | **97th P** | **DIF** | **Median** | **DIF** | **97th P** | **DIF** | **%** |
| **6** | **32.5** | 4.3 | 49.2 | 3.6 | 0.44 | 0.00 | 0.48 | -0.02 | **2.88** | 0.38 | 4.24 | 0.44 | 13.7 |
| **7** | **29.3** | 0.4 | 43.6 | -1.2 | 0.44 | 0.01 | 0.50 | 0.01 | **2.88** | 0.28 | 4.29 | 0.09 | 6.2 |
| **8** | **31.1** | 0.7 | 50.7 | -1.9 | 0.43 | 0.01 | 0.49 | 0.00 | **3.05** | 0.25 | 5.12 | 0.42 | 7.8 |
| **9** | **33.0** | -0.9 | 53.8 | -2.0 | 0.43 | 0.01 | 0.50 | 0.01 | **3.52** | 0.42 | 6.02 | 0.82 | 10.9 |
| **10** | **33.6** | -1.4 | 53.6 | -3.3 | 0.43 | 0.01 | 0.50 | 0.01 | **3.68** | 0.38 | 6.32 | 0.62 | 7.8 |
| **All** | **32.0** | 0.8 | 50.2 | -0.1 | 0.44 | 0.01 | 0.50 | 0.00 | **3.14** | 0.34 | 5.27 | 0.48 | 9.9 |

Explanations: DIF – differences between respective parameters and IDEFICS standards,
>97th P (%) – the prevalence of girls with FMI higher than 97th percentile is expressed as a percentage. Bold figures indicate significant higher values of ST and FMI as compared with boys displayed in Table 3.

Taking into account also WHtR and FMI, overall 68% boys and 69% of girls would be classified as “normal” instead of 79% and 81% respectively using just BMI. Only in 2.1% of overweight boys and 1.2% of girls, normal FMI was found (fake obesity) as compared with hidden obesity in 7.3%, and 9.9% respectively in normal weight or even lean children. In all children classified by BMI as obese, WHtR and FMI met the level of obesity (Fig. 1).

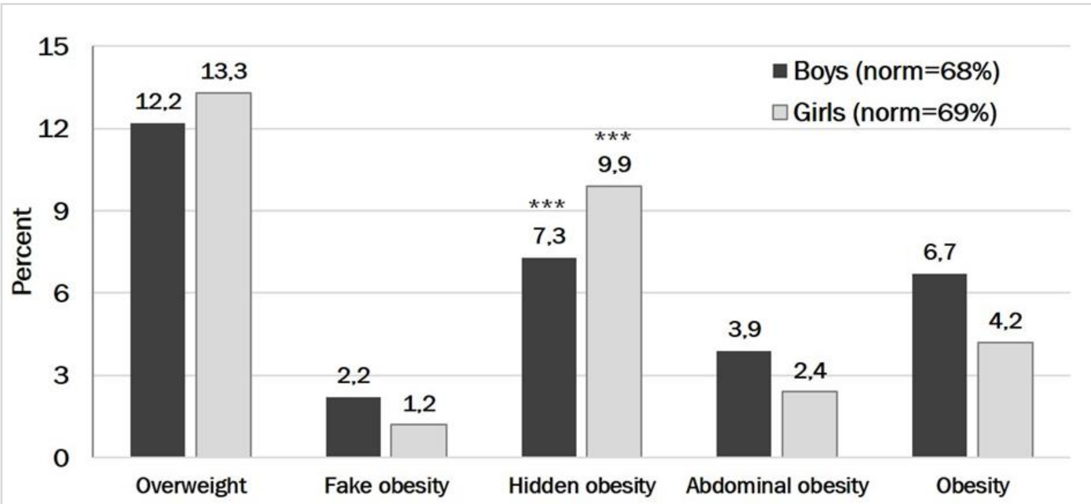


Fig. 1: Types of obesity determined by body mass index, fat mass index, and waist-to-height ratio
*** – p<0.001 vs fake as well as vs abdominal obesity.

## Discussion

Higher AP scores in Bratislava children compared to Slovak standards (Regecová et al. 2015) and results of the National anthropometric survey (NAS) 2011(Regecová et al., 2016) indicate not only the continuation of the secular trend but may also reflect the persisting differences in living conditions in Slovak regions. (Regecová et al. 2015). Interestingly, the prevalence of overweight and obesity assessed by BMI matched with recent findings (Tichá et al. 2018) and fit to the middle of the range Slovakia and most of the European countries (Wijnhoven et al. 2014, Ezzati et al. 2017, Ahrens et al. 2011). Mean and median values of subscapular and triceps skinfolds were similar to values in children from Jena measured in 2005/2006 (Kromeyer-Hauschild, Glässer and Zellner 2012), subscapular SF slightly lower than Polish (Jaworski et al. 2012), but higher than USA references (Addo and Himes 2009) and Czech boys (Vignerová and Bláha 2006). Waist-to-height ratio remained almost the same across age range in both genders and agreed well with IDEFICS study(Nagy et al., 2014). However, the comparison of the fat mass index with the same data source (Nagy et al. 2016) had shown that in a relatively high proportion of children the fat content exceeded the level of $97^{th}$ P in spite of normal BMI. Comprehensive studies (Pařízková 2014, Olds 2009, Wells et al., 2002) document that along with the acceleration of growth in the general population during recent decades, fat content has been increasing relatively more and disproportionately as compared to the other body tissues. Increased fatness has been manifesting even when the BMI has not changed markedly. Partition the relative contribution of fat and fat-free mass components to a secular increase revealed, the average (age- and sex-adjusted) increase in body mass was 1.4 kg per decade. Of this, increases in a fat mass represented 0.8 kg, and increases in a fat-free mass represented 0.6 kg (Olds 2009). Greater disparities between BMI and fat mass demonstrated in normal weight categories as compared with overweight and obese suggest that body weight within normal limits does not always mean also “healthy” weight and points at least to insufficient physical activity of these children. For these reasons, it would be highly desirable to extend the study upon national representative data and clarify the relationship, between fat mass and BMI with respect to age and developmental stage.

**Conclusion**

Examined children from Bratislava are higher and heavier compared to the rest of Slovakia but do not differ in the prevalence of obesity assessed by BMI. In none of the children, BMI was increased due to excessive development of the lean mass, what can be expected only in a small part of overweight children. The opposite fail was much more likely by normal BMI, as about 10% of children with high fat component remained ”hidden”. Overall, the analysis had shown relatively good compliance between all three definitions regardless they are based on BMI (IOTF), waist-to-height ratio and fat mass index. In young school age, the BMI remains a good tool to identify obesity, especially in epidemiological surveys. For clinical use, more body composition and proportionality measures may help uncover the potential health risk even in lean children.

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