ORIGINAL PAPERS

Assessment of anthropometric measurements in diagnosis and monitoring of excessive body weight in children

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A – Study Design, **B** – Data Collection, **C** – Statistical Analysis, **D** – Data Interpretation, **E** – Manuscript Preparation, **F** – Literature Search, **G** – Funds Collection

Summary **Background.** Obesity developing in the early years is one of the most important risk factors for cardiovascular diseases. This contributes to the need for the earliest possible diagnosis of overweight in children. There is a noticeable underdiagnosis of obesity, most often in children between 5 and 12 years of age, as well as in adolescents.
Objectives. The aim of the study was to estimate the correlation between anthropometric measurements that are most commonly used in the diagnosis of obesity.
Material and methods. The study involved 150 children, during their rehabilitation and wellness stay at CRR KRUS in Szklarska Poreba in 2017. The entire group performed basic anthropometric measurements – height, body weight, waist circumference and thickness of the deltoid skin fold. Body composition analysis was performed using the Tanita analyzer.
Results. A statistically significant correlation between the studied parameters was assumed ($p < 0.001$). The parameter showing the highest level of correlation with other measured parameters was the BMI percentile, BMI value and Cole index. Among the parameters not based on growth and weight in the boys' group, the most important was the percentile of the waist circumference ($r = 0.76$), while in the girls' group, the content of adipose tissue ($r = 0.74$).
Conclusions. The BMI and centile BMI results were the parameters of the highest value in the diagnosis and monitoring of excessive body weight in children. In addition, neither weight nor growth measurements should be used to determine the amount and location of adipose tissue.
Key words: obesity, Body Mass Index, body composition, pediatrics, anthropometry, waist circumference.

Background

The awareness of the problem of obesity among children and teenagers is gradually increasing. Thanks to the widespread preventive activities and campaigns promoting a healthy lifestyle to the younger populations, numerous developed countries have succeeded in limiting the increase in the number of children with a confirmed diagnosis of obesity [1]. It has been observed that the percentage of younger populations with overweight is decreasing, which is also the case in Poland. According to data from the year 2010, 17.8% of Polish students suffered from overweight or obesity, whilst in the year 2014, only 14% [2]. Despite this positive trend, it should be noted that the average value of BMI between the years 1975 and 2016 gradually grew by 1 kg/m^2 in Middle Eastern Europe and that this rate was three times higher than among the world population [2]. The consequences of this dramatic rise may appear in the decades to come. It has been proven that obesity developing in early age bears a much higher risk of cardiovascular diseases than obesity developed in adulthood [3]. Moreover, children who are affected by obesity had reduced cognitive performance and presented changes in brain structures responsible for learning

and memory compared to their non-obese peers [4]. This may obviously affect their school performance. Considering these facts, there is a necessity for the earliest possible diagnosis of increased body mass among children and teenagers. This may have a positive impact on the quality of their life in its further stages. For the time being, however, figures show that under-diagnosis of obesity predominantly concerns children between the age of 5 and 12. This is also frequent with teenagers, but comparatively less common among adults [5]. In the diagnostics of abnormal body mass in pediatric patients, doctors tend to adapt BMI with the reference to the applicable centile grids or using the Cole index, which is recommended by the IOTF (International Obesity Task Force). BMI cut-off values may differ between countries; in North America, obesity is diagnosed when BMI exceeds the 95th centile, but in some European countries, the threshold is marked at the 97th centile. Even though calculating BMI requires two basic parameters (weight and height), which should be obtained during every preventive outpatient visit, underdiagnosis of obesity is frequent. Patel et al. proved that only 18% of children matching the diagnostic criteria had a documented diagnosis of obesity [6]. WHO defines obesity as "a medical condition in which excess body fat accumulation can impact health negatively". As the definition shows, BMI is

an intermediary anthropometric index which does not convey any information about the accurate contents of fat tissue in the patient's body. Additionally, more and more attention is drawn to the problem of abdominal obesity, which seems to be more strongly corelated with the risk of cardiovascular factors than general obesity [7]. Epidemiological data shows that abdominal obesity may affect one out of ten children in Poland, and it is more common in boys, especially in older age groups, with eating habits and lack of physical activity being the most relevant risk factors [8]. In the assessment of abdominal obesity, the most frequently used parameters are WC (waist circumference) and WHR (waist height ratio). Another parameter associated with excess fat tissue is skinfold thickness, usually measured above the triceps muscle or in subscapular area. However, its accuracy may be biased by common errors made during measurement [9]. Interestingly, WC was proved to have a stronger correlation with insulin resistance than BMI or skinfold thickness [10]. There has been a growing trend towards the use of body composition analyzers based on bioimpedance, which allows precise estimation of FFM (fat free mass) and FM (fat mass). This low-cost method was validated in tests comparing its accuracy to reference imaging techniques [11]. The ability to adapt so many parameters in diagnosing obesity may facilitate the diagnosis and minimize the frequency of underdiagnosis.

Objectives

The purpose of this study was to test the correlation between anthropometric indicators predominantly applied in the diagnostics of obesity and body composition estimated by bioimpedance analysis (BIA).

Materials and methods

Study design and participants

The analysis of anthropometric parameters and body mass composition were a part of a rehabilitatory stay for children from rural areas held at the Granit Hotel in Szklarska Poreba (Poland). The research was carried out in July 2017. The camp was organized for children with upper respiratory tract disorders. Body mass composition analysis was carried out using the Tanita device.

Anthropometric measurements were the elements of a medical examination which was part of medical care during the rehabilitation treatment camp. Therefore, the authors did not request permission from the bioethical committee.

Data sources/measurement

We measured parameters such as: body weight, height, thickness of skin folds over the triceps brachii muscle, waist circumference and body composition (content of adipose tissue, muscle tissue, water and bone mass). Additionally, indicators such as BMI, WHtR and Cole index were calculated.

Statistical methods

Microsoft Excel 2017 was used to prepare the database, while statistical analysis was performed using the Statistica computer program (StatSoft Inc.). To evaluate the distribution curve, the Shapiro–Wilk test was used, while the correlation between the obtained parameters was estimated using the Spearman's rank correlation test. In all analyzed parameters, the value of $p < 0.05$ was assumed to be the statistical significance level. There wasn't any missing data, and all planned measurements were performed.

Results

The analysis of normal distribution revealed that none of the analyzed variables had a normal distribution; therefore, non-parametric tests were used in statistical analysis. We included all obtained data in the further analysis.

Participants and descriptive data

Table 1. Characteristics of the analyzed group of children. The results are presented as the median, maximum and minimum values (range)			
Characteristics of the research group			
Gender	**Girls**	**Boys**	**Summary**
Population	82	68	150
Age [years]	12 (7–15)		
Illness — Bronchial asthma	28.1%	42.6%	34.7%
Illness — Recurrent upper respiratory tract infections	75.6%	60.3%	68.7%
Illness — Allergic rhinitis	14.6%	10.3%	12.7%
Weight [kg]	46.3 (19.1–98)	46.7 (21.3–82.4)	46.5 (19.1–98)
Height [cm]	154 (117–177)	152 (124–180)	153 (117–180)
BMI [kg/m²]	19.5 (13.1–34.9)	19.3 (13–31.6)	19.4 (13–34.9)
FM [%]	26.6 (17.9–46.4)	22.4 (13–49.1)	24.8 (13–49.1)
Waist circumference [cm]	74 (52–103)	75 (54–110)	74 (52–110)
Skin fold [mm]	17 (7–40)	19 (5–40)	18 (5–40)
WHtR	48 (40–61)	49 (40–76)	49 (40–76)

Main results

Analysis without grouping

The mutual correlation between body mass, body weight percentile, BMI, BMI percentile, Cole index, body fat mass, waist circumference percentile, skinfold thickness percentile and WHtR index was, in all cases, statistically significant [Spearman's rank correlation, $p < 0.001$].

Analysis of the examined parameters depending on gender

Due to the small number of children aged 7 and 8 years, an analysis was not conducted in these age-groups. The analysis was carried out in groups of children 9–15 years of age.

An analysis of correlation values between the examined parameters revealed that the parameter showing the highest level of correlation with other measured parameters was found in the group of girls BMI percentile, the BMI value and Cole index. All these indicators analyze the body weight and height of the examined child. Among the parameters, which are independent of these variables, the content of adipose tissue and WHtR were the most useful. In the group of boys, the highest correlation value with other parameters was also shown by the BMI percentile, BMI and Cole index values. From parameters independent of these variables, the highest value was showed by the waist circumference percentile (Tables 2, 3).

In the group of children aged 9–12 and 14 years, the most useful parameters were: BMI, BMI percentile and Cole index. In the group of children 13 years of age, the body mass percentile along with the above-mentioned parameters were most helpful. In the age group of 15 years, BMI and BMI percentile did not show a sufficient correlation with other parameters, whereas the body mass percentile and Cole index were characterized by a high level of correlation with other parameters. From the group of the remaining elements – not based on body mass and height – the percentile of waist circumference was characterized by the highest level of correlation with other parameters (Table 4).

Table 2. Correlation values (r) between the analyzed parameters depending on gender.
All correlations in the table are statistically significant with p < 0.001 [Spearman's correlation rank]

Sex	Girls								
	Parameter	Body mass	Body mass percentile	BMI[1]	BMI percentile	Content of adipose tissue	Waist circumfer-ence[2]	Skin fold[3]	WHtR[4]	Cole index[5]
Boys	Body mass	–	0.76	0.92	0.73	0.72	0.57	0.50	0.56	0.73
	Body mass percentile	0.71	–	0.87	0.95	0.73	0.74	0.56	0.74	0.97
	BMI	0.84	0.85	–	0.91	0.80	0.71	0.60	0.75	0.89
	BMI percentile	0.68	0.88	0.96	–	0.78	0.76	0.62	0.84	0.97
	Content of adipose tissue	0.42	0.68	0.63	0.68	–	0.60	0.74	0.79	0.76
	Waist circumfer-ence	0.65	0.75	0.73	0.70	0.78	–	0.49	0.82	0.78
	Skin fold	0.71	0.68	0.72	0.64	0.76	0.86	–	0.65	0.59
	WHtR	0.44	0.60	0.63	0.64	0.86	0.90	0.81	–	0.77
	Cole index	0.70	0.95	0.93	0.97	0.67	0.73	0.66	0.63	–

[1] BMI – Body Mass Index; [2] Waist circumference related to centile charts. Correlation depending on the percentile of waist circumference; [3] Skin fold – measured over the triceps brachii muscle, expressed in percentiles; [4] WHtR – waist-to-height ratio; [5] Cole index – [(measured body weight x proper height – 50th percentile)/(measured height x proper body mass – 50th percentile) x 100%].

Table 3. Averaged correlation value between analyzed parameters. All correlation values were statistically significant with p < 0.001.

Parameter	Average correlation coefficient relative to all other elements	
Sex	Girls	Boys
Body mass	0.69	0.64
Body mass percentile	0.79	0.78
BMI	0.81	0.79
BMI percentile	0.82	0.77
Content of adipose tissue	0.74	0.69
Waist circumference percentile	0.68	0.76
Skin fold percentile	0.59	0.73
WHtR	0.74	0.69
Cole index	0.81	0.78

Table 4. Averaged correlation values (r) between analyzed factors. Only statistically significant correlation values with p < 0.05 were taken into account

Parameter	Average correlation relative to all other elements						
Age	9	10	11	12	13	14	15
Body mass	0.8	0.86	0.9	0.86	0.73	0.81[3]	0.83[1]
Body mass percentile	0.82	0.85	0.9	0.86	0.82	0.76[3]	0.84[1]
BMI	0.87	0.89	0.93	0.86	0.78	0.81[3]	–
BMI percentile	0.87	0.89	0.94	0.86	0.78	0.81[3]	–
Content of adipose tissue	0.81	0.8	0.89	0.78	0.55	0.53	–
Waist circumference percentile	0.87	0.84	0.91	0.82	–*	0.64	0.53[2]
Skin fold percentile	0.77	0.82	0.76	0.74	–*	0.62[4]	–
WHtR	0.83	0.77	0.84	0.77	0.53	0.65	–
Cole index	0.89	0.88	0.92	0.86	0.81	0.79[3]	0.86

[1] No correlation with parameters: adipose tissue mass, percentile of skin fold thickness over the triceps brachii muscle, WHtR; [2] correlation with body mass, body mass percentile and Cole index; [3] no correlation with the percentile of skin fold thickness over the triceps brachii muscle; [4] correlation with adipose tissue mass, waist circumference percentile and WHtR.

Discussion

Key results

Based on the results obtained, it can be concluded that the BMI and BMI centile measurement had the highest correlation with other anthropometric measurements. Among the tested parameters not based directly on the value of body mass and growth, the waist circumference centile turned out to be the most useful. Adipose tissue content showed a positive correlation with overweight and obesity. Differences in the useful-ness of this test depending on gender may be connected with

a higher content of muscle tissue in boys and the distribution of adipose tissue characteristic for the given gender [12]. The measurement of skin fold thickness belongs to the group of inexpensive, easily accessible and non-invasive methods of testing body composition [13]. According to Spanish researchers, skin fold thickness is also an appropriate indication of adipose tissue distribution in children and teenagers and has a positive correlation with general cardiovascular risk [14].

Limitations of the study

The largest disadvantage of using only the BMI measure is the inability to distinguish adipose tissue mass from lean mass [15]. For this reason, the BMI standards commonly used in adults should not be used to diagnose overweight and obesity in children. Therefore, the use of growth charts appropriate for gender and age is recommended, in which limit points are positioned, depending on the source, on centile 85 and 95 or 90 and 97, for overweight and obesity, respectively [16, 17].

In other analyses, the usefulness of waist circumference centile in pediatric offices was noted, which is supported by the simplicity of performance, evaluation and high effectiveness in prevention of excessive body weight. The test restrictions were underweight and overweight limits, common for a diverse testing group with respect to nationality [18]. The high sensitivity and specificity of this test was shown both in determination of adipose tissue content and predispositions to future occurrence of diseases of civilizations [19]. The changes taking place in the course of growth and puberty have a minor effect on this result [20]. Other authors, apart from the undeniable advantages of bioimpedance, such as simplicity of performance and price of the test, indicate frequent underestimation of measurements performed using this method. Furthermore, the measurement error for adipose tissue is proportional to BMI and waist circumference [21]. Fluctuations in the quantity of water in the organism depending on age were seen, especially among younger age groups. This may have an effect on the measurement error in the evaluation of adipose tissue content [22].

Unfortunately, measurement of skin fold thickness did not turn out to be the most precise in this study, and the reasons for such results can be due to both inaccuracy and the limited experience of the research persons, as well as in limitations of this method resulting from adipose tissue distribution. According to the authors of studies of anthropometric measurements, an experienced researcher can achieve repeatability of results with differences between individual results up to 5% [23]. The ratio of subcutaneous adipose tissue to total adipose tissue in the organism is not a constant value and may vary within the population. Additionally, the amount of subcutaneous adipose tissue may remain within the standard in persons with mild undernutrition [13].

Interpretation

It was proven that BMI has a high correlation with respect to parameters such as WHtR, waist circumference and skin fold, which was also confirmed by this research [8, 24]. However, for many, the degree of correlation is insufficiently high, which is why the use of BMI in clinical practice, in spite of its simplicity of measurement and calculation, is a disputable issue [25, 26].

Generalization

Many studies confirm that increased BMI for a given age is connected with a higher risk of cardiovascular disease. In addition, in nearly half of children with BMI above centile 97, at least one disorder occurs which is a part of the metabolic syndrome [8, 27]. In children, apart from the content of adipose tissue itself, its distribution in the organism is essential. In the case of the identical total content of adipose tissue in the tested children, its location will have an effect on the risk of cardiovascular diseases [28, 29].

Conclusions

In summary, it can be concluded that none of the discussed tests fulfils all the criteria for an ideal diagnostic test for obesity in children and predilection for the occurrence of metabolic syndrome and cardiovascular incidents in adulthood.

The parameters showing the highest value in the monitoring of children's body mass (which correlates in the highest degree with all other measured parameters) in almost all studied groups are: BMI value, BMI percentile and Cole index – all based on height and body mass.

Among the factors which are not based on body height and weight, the most useful indicator in the group of boys seems to be percentile of waist circumference, while among girls – the content of adipose tissue.

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