Int. J. Morphol.,
42(2):324-331, 2024.

Anthropometric Characteristics, Body Composition and Nutritional Status of Younger Primary School Children in Montenegro: National Study

Características Antropométricas, Composición Corporal y Estado Nutricional de los Niños más Pequeños de la Escuela Primaria en Montenegro. Estudio Nacional.

Rajko Milasinovic[1]; Ana Popovic[2]; Jovica Petkovic[3]; Kosta Goranovic[3] & Marko Joksimovic[3]

MILASINOVIC, R.; POPOVIC, A.; PETKOVIC, J.; GORANOVIC, K. & JOKSIMOVIC, M. Anthropometric characteristics, body composition and nutritional status of younger primary school children in Montenegro. National study. *Int. J. Morphol., 42(2)*:324-331, 2024.

SUMMARY: This article has two aims: (a) first aim was to determine what is the most applicable and the simplest alternative for recommended BMI categories for underweight, overweight and obesity related to IOTF references, from the practical standpoint; (b) second aim was to determine the prevalence of the nutritional status in Montenegro on this representative sample of school children aged 9-13 years and compare them with peers from relevant and similar studies from both the local region and globally. A total sample of 1478 healthy children from Montenegro participated in this study divided into two sub-samples of 732 girls and 746 boys. According to the IOTF body mass index (BMI) reference values were used through ROC curve analysis to evaluate potential alternatives for estimation of the nutritional status of this sample of children. Only WHtR did not show significant age-related differences in the case of both genders. Considering the nutritional status of children from this study it has been found that boys have a considerably higher prevalence of being overweight (22.7 % vs. 16.4 %) and obese (7.5 % vs. 3.3 %) compared to girls. On the other hand, girls were more prevalent to be underweight (10.5 % vs. 7.5 %). WHtR seems like the best alternative for the estimation of obesity and being overweight due to simplicity and the equipment needed.

KEY WORDS: Underweight; Overweight; Obesity; Waist to height ratio; Skinfold.

INTRODUCTION

The presence of obesity and being overweight is a ubiquitous problem of pandemic proportions in both adults and children (Ng *et al*., 2014). The scientific community has given special attention to the investigation of this phenomena, which has resulted in the conclusion that excessive body mass and obesity in childhood ultimately increases the health risks during adulthood and life span (Rolland-Cachera *et al*., 2015). Namely, according to a recent report from the World Health Organisation (WHO) and World Obesity Federation (WOF) compared with children who have a healthy weight, those with obesity or are overweight are more likely to experience multiple negative consequences, such as poorer health in childhood and adulthood, lower self-esteem and school achievements and consequently poorer employment potential (World Health Organization, 2018). Furthermore, from 1980-2013 the prevalence of being overweight and obese has risen by 27.5 % in adults, and by 47.1 % in children globally (Ng *et al*., 2014), which basically represents an almost twofold increment in children. Therefore, regular monitoring of the nutritional status and body composition in children during schooling represents a crucial step in public health prevention and eventual timely intervention to reduce the accompanying risk factors.

Methods for determining nutritional status or body composition are quite different and each of them has its advantages and disadvantages, which basically refers to either precision or the number of subjects that can be measured in a given time frame (Hu, 2008). For example, laboratory methods can provide numerous quantitative and qualitative data with relatively high precision and reliability,

[1] PhD student, Faculty of Sport and Physical Education, University of Montenegro, Niksic, Montenegro.
[2] Clinic of Dermatology and Venereology, Clinical Center of Montenegro, Podgorica, Montenegro.
[3] Faculty of Sport and Physical Education, University of Montenegro, Niksic, Montenegro.

Received: 2023-12-15 Accepted: 2024-01-09

but they are limited in the number of subjects tested per session. In contrast, the simpler techniques, although less precise and reliable, are proven to be very effective and accurate enough, especially in large epidemiologic or population studies (Hu, 2008). The most widely used method for determining nutritional status in children has been through body mass index (BMI), which has shown to be highly challenging for analysis due to turbulent growth and development during childhood, especially in puberty. For that reason, measures of body fatness and muscularity are often recommended when one wants to analyse the nutritional status of children more accurately, which can be done either by the use of laboratory equipment or field equipment such as a calliper for skinfold thickness (Dezenberg *et al*., 1999; Hu, 2008).

In that regard, three leading institutions in epidemiologic research WHO, IOTF (Cole *et al*., 2000, 2007), and the Center for Disease Control and Prevention (CDC) (Kuczmarski *et al*., 2000) developed BMI standards for the population of children that they measured. Following this practice, some countries developed their national BMI references, regardless of WHO, IOTF and CDC. In addition to BMI some effort has been given to the development of body fat standards and valid estimations of percentage of body fat (PBF) from the whole set of skinfold thicknesses (Dezenberg *et al*., 1999). More recently, direct and indirect measures of central obesity were also introduced, because a series of studies have confirmed that these measurements highly correlated with the majority of risk factors related to obesity and being overweight, suggesting that they may be potentially more important to follow than BMI in both adults and children (Ashwell *et al*., 2012). So far, the biggest obstacle in the general acceptance of the measurement of the waist circumference is the lack of consensus or clear definition from the aspect of defining a clear anatomical location, since there is a whole set of different variations in use (Magalhães *et al*., 2014; Sharma *et al*., 2015).

This solution is particularly useful in countries that do not have developed national growth and BMI references, such as the case in Montenegro. Technological development and sedentary behaviour are not affecting only the adult population and developed countries in terms of obesity and being overweight, the same trend is present between school children and in developing countries such as Montenegro (Wang & Lobstein, 2006).

This article has two aims: (a) first aim was to determine what is the most applicable and the simplest alternative for recommended BMI categories for underweight, overweight and obesity related to IOTF references, from the practical standpoint; (b) second aim was to determine the prevalence of the nutritional status in Montenegro on this representative sample of school children aged 9-13 years and compare them with peers from relevant and similar studies from both the local region and globally.

MATERIAL AND METHOD

Sample of participants. The sample size consisted of 1478 healthy children, divided into two groups by sex (boys and girls) and five subgroups by age (9, 10, 11, 12, and 13 years of age). The main characteristics for the boys were: N = 746 (50.5 %), mean±SD age = 10.95±1.41 years, body height = 153.24±11.18 cm, and body mass = 46.13±13.19 kg; and for the girls: N = 732 (49.5 %), age = 10.98±1.38 years, body height = 152.25±10.24 cm, and body mass = 43.92±11.51 kg. All measurements were collected during the school year 2017/18. The children sampled were from nine cities and from three major regions of the country: northern (Pljevlja, Bijelo Polje and Zabljak), central (Niksic, Danilovgrad and Podgorica) and southern (Herceg Novi, Budva and Bar). School principals, parents and children were informed about the purpose of the measurement and children were measured only if everybody signed consent forms prior to the measurements being taken. The research was carried out in accordance with the conditions of the declaration of Helsinki.

Research design

Anthropometry. The anthropometric variables of body height (m), body mass (kg), were measured in each subject. Body height and body mass measurement were made on a leveled platform scale (Ano Sayol, Barcelona, Spain) with an accuracy of 0.01 kg and 0.001 m, respectively. Body mass index (BMI) was calculated from body mass and body height. All measurements were taken between 09:00-09:30in the morning.

Body composition. Body composition and nutritional status were estimated from the common measures of anthropometric characteristics and skinfold thickness. The waist circumference (WC) was measured using a Gulick tape (North Coast Medical Inc., USA), with precision of 0.1 cm. WC was measured according to the previously reported procedure (Sharma *et al*., 2015), in short, the measuring tape was placed midpoint between the last rib and iliac crest. Furthermore, WC and BH were used for calculation of waist to height ratio (WHtR) by the formula WHtR = WC (cm) / BH (cm). The skinfold thickness (SF) was measured using the Gima 2 skinfold caliper (Gima S.p.A, Italy), with precision of 0.1 mm. The SF thickness measurements were taken at four different anatomical locations: triceps, biceps, subscapular and abdominal and according to standardised descriptions of skinfold sites and procedures by recommendations from the American College of Sport Medicine (Pescatello *et al*., 2013). Finally, Triceps and Subscapular were also used to estimate the percentage of body fat (PBF) according to (Slaughter *et al*., 1988).

Statistical analysis. The basic descriptive statistics for means and standard deviations (SD) were calculated using SPSS 20.0 (IBM, Chicago, USA). Age-related differences (maturation effects) within the same sex were analysed using the one-way ANOVA analysis ($p < 0.05$). Receiver operating characteristics (ROC) curve method was used to evaluate the discriminative power of tests trough sensitivity and specificity of nine variables related to the estimated BMI by age and sex IOTF specific cut-off values for children. These values are equivalent to the widely accepted categorisation for adults: underweight (UW) < 18.5 kg/m^2, overweight (OW) ≥ 25 kg/m^2 and obese (OB) ≥ 30 kg/m^2. The discriminative power of tests was classified according to Hosmer Jr. *et al*. (2013), based on the area under the ROC curve (AUC) values: no discrimination = 0.5, poor = 0.5 ≤ 0.7, acceptable = 0.7 ≤ 0.8, excellent = 0.8 ≤ 0.9, and outstanding = > 0.9. The criteria for optimal cut-off values were calculated by two commonly used methods: the distance to upper left corner,

$$DTC = \sqrt{(1 - \text{sensitivity})^2 + (1 - \text{specificity})^2}$$

and the Youden Index,

$$YI = \text{sensitivity} + \text{specificity} - 1.$$

The prevalence was presented by percentages and stratified by sex and age and in the whole sample according to IOTF references.

RESULTS

The main descriptive data for mean and standard deviation adjusted for sex and age are shown in Table I.

The results obtained by one-way analysis of variance (ANOVA) for each from evaluated variables showed a significant influence of maturation ($p<0.05$), while WHtR was only age independent, regardless of sex, for boys ($F = 0.817$, $p = 0.514$) and girls ($F = 1.625$, $p = 0.166$).

The AUC results with 95 % confidence interval and standard errors are shown in Table II. The highest discriminative power for underweight girls occurred in SUM4, followed by percentage of body fat and SUM2 with an outstanding classification, while abdominal skinfold,

Table I. Descriptive statistics by sex and age.

Sex	Years (n)	BH (cm) Mean	BM (kg) Mean	BMI (kg/m^2) Mean	WC (cm) Mean	WHtR Mean	TrSF (mm) Mean	BiSF (mm) Mean	SsSF (mm) Mean	AbSF (mm) Mean	SUM2 (mm) Mean	SUM4 (mm) Mean	PBF (%) Mean
		SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD
Girls	9	141.11	34.70	17.29	62.53	0.443	14.4	10.1	9.7	13.8	24.1	48.1	22.47
	(133)	6.45	7.83	3.02	7.71	0.047	5.3	5.0	6.0	8.8	10.8	23.5	10.20
	10	146.89	39.38	18.09	66.31	0.451	15.4	11.4	11.0	17.0	26.4	54.8	24.83
	(164)	7.22	8.85	2.92	9.47	0.056	6.2	5.2	5.6	8.8	11.1	23.8	10.97
	11	151.96	42.07	18.11	66.27	0.436	14.4	10.1	9.9	15.4	24.2	49.8	22.59
	(156)	7.07	8.59	2.87	8.10	0.049	4.6	4.4	4.9	8.2	8.7	19.7	8.46
	12	159.00	50.01	19.74	70.26	0.442	15.3	10.4	12.2	18.8	27.5	56.7	25.55
	(139)	6.59	9.64	3.44	9.14	0.058	5.3	4.7	6.2	10.0	10.9	23.9	10.62
	13	162.75	53.98	20.32	72.43	0.445	16.1	11.5	12.8	19.3	29.0	59.8	27.14
	(140)	6.51	11.13	3.69	9.36	0.054	5.8	5.9	6.4	9.0	11.5	25.2	11.44
Boys	9	142.79	36.46	17.75	64.31	0.450	13.9	9.1	9.2	14.3	23.0	46.5	21.69
	(147)	6.07	8.25	3.17	8.80	0.054	5.3	4.6	5.4	10.2	10.3	24.1	10.00
	10	147.19	41.31	18.93	67.68	0.459	15.4	10.6	10.7	18.3	26.1	54.9	24.86
	(174)	6.54	10.14	3.80	10.30	0.063	6.5	5.4	7.2	12.1	13.1	29.3	12.81
	11	151.71	44.78	19.30	69.01	0.454	15.5	10.3	10.6	18.9	26.2	55.4	24.69
	(135)	6.70	10.77	3.69	10.72	0.062	6.1	5.8	6.4	12.9	11.9	29.5	11.73
	12	159.15	51.77	20.24	72.80	0.457	15.4	10.5	12.0	19.6	27.3	57.4	25.73
	(148)	8.65	12.85	3.68	10.84	0.063	7.1	6.4	8.4	13.7	14.7	33.0	14.09
	13	166.77	57.44	20.51	74.98	0.450	13.3	8.9	10.7	17.5	24.0	50.4	22.85
	(142)	8.16	12.26	3.52	10.71	0.061	5.9	5.1	5.8	12.0	11.3	27.4	11.16
Girls	10.98	152.25	43.92	18.69	67.53	0.444	15.1	10.7	11.1	16.9	26.2	53.8	24.50
Total	(732)	10.24	11.51	3.37	9.40	0.053	5.5	5.1	5.9	9.2	10.7	23.6	10.49
Boys	10.95	153.24	46.13	19.33	69.66	0.454	14.7	9.9	10.6	17.7	25.4	53.0	23.99
Total	(746)	11.18	13.19	3.71	10.92	0.061	6.3	5.5	6.8	12.3	12.4	29.0	12.14

Note. BH – body height; BM – body mass; BMI – body mass index; WC – waist circumference: WHtR – waist to height ratio; TrSF – triceps skinfold; BiSF – biceps skinfold; SsSF – subscapular skinfold; AbSF – abdominal skinfold; SUM2 – sum of 2 skinfold; SUM4 – sum of 4 skinfold; PBF – percentage of body fat.

subscapular skinfold, WC, WHtR, triceps skinfold and biceps skinfold were classified as excellent. Regarding the underweight boys, the best discriminative power occurred in subscapular skinfold, followed by WHtR, SUM4, WC, percentage of body fat, SUM2, abdomen skinfold, triceps skinfold and biceps skinfold with an excellent classification. For overweight girls, the highest discriminative power occurred with WHtR, followed by percentage of body fat, SUM2, subscapular skinfold, SUM4 and WC with an outstanding classification, while abdomen skinfold, triceps skinfold and biceps skinfold were considered as excellent tests. In the case of overweight boys the best alternative for the existing test was subscapular skinfold, followed by WHtR, SUM4, percentage of body fat, SUM2, WC, abdominal skinfold, biceps skinfold and triceps skinfold wherein all tests were classified as outstanding. For estimation of obesity levels in the case of girls, the best alternative to IOTF BMI reference values was subscapula skinfold, followed by percentage of body fat, SUM2, SUM4, WHtR, WC, abdominal skinfold, triceps skinfold, biceps skinfold and all tests were considered as outstanding by discriminative power. Furthermore, the best alternative for obesity estimation in boys was WHtR, followed by SUM4, percentage of body fat, SUM2, subscapular skinfold, WC, abdominal skinfold, biceps skinfold and triceps skinfold and in this category all tests were classified as outstanding.

Optimal cut-off values calculated and extracted from ROC analysis by two methods DFC and YI with sensitivity and specificity of each cut-off point are shown in Table III.

Table II. AUC results for variables stratified by sex and related to IOTF references for underweight, overweight and obese.

Sex	Variable	Underweight		Overweight		Obesity	
		AUC (95% CI)	SE	AUC (95% CI)	SE	AUC (95% CI)	SE
Girls	WC	0.882 (0.846-0.917)	0.018	0.923 (0.902-0.944)	0.011	0.976 (0.962-0.989)	0.007
	WHtR	0.869 (0.835-0.904)	0.018	0.944 (0.926-0.963)	0.009	0.978 (0.963-0.992)	0.008
	TrSF	0.862 (0.825-0.900)	0.019	0.890 (0.859-0.920)	0.015	0.957 (0.933-0.982)	0.012
	BiSF	0.859 (0.819-0.898)	0.020	0.876 (0.846-0.906)	0.015	0.956 (0.935-0.977)	0.011
	SsSF	0.893 (0.860-0.927)	0.017	0.937 (0.919-0.956)	0.009	0.981 0.969-0.994	0.006
	AbSF	0.893 (0.861-0.924)	0.016	0.898 (0.870-0.926)	0.014	0.958 (0.926-0.990)	0.016
	SUM2	0.904 (0.872-0.935)	0.016	0.937 (0.919-0.955)	0.009	0.980 (0.966-0.993)	0.007
	SUM4	0.914 (0.886-0.943)	0.015	0.936 (0.918-0.955)	0.010	0.979 (0.965-0.993)	0.007
	PBF	0.904 (0.872-0.935)	0.016	0.937 (0.919-0.955)	0.009	0.980 (0.966-0.993)	0.007
Boys	WC	0.872 (0.827-0.916)	0.023	0.939 (0.921-0.957)	0.009	0.958 (0.942-0.974)	0.008
	WHtR	0.876 (0.842-0.910)	0.017	0.954 (0.938-0.971)	0.008	0.978 (0.965-0.990)	0.006
	TrSF	0.830 (0.791-0.870)	0.020	0.915 (0.891-0.939)	0.012	0.925 (0.898-0.951)	0.013
	BiSF	0.817 (0.776-0.859)	0.021	0.918 (0.896-0.940)	0.011	0.938 (0.915-0.961)	0.012
	SsSF	0.887 (0.856-0.918)	0.016	0.955 (0.940-0.970)	0.008	0.960 (0.944-0.977)	0.008
	AbSF	0.861 (0.826-0.895)	0.018	0.933 (0.914-0.952)	0.010	0.939 (0.916-0.962)	0.012
	SUM2	0.871 (0.838-0.905)	0.017	0.947 (0.928-0.965)	0.009	0.960 (0.944-0.975)	0.008
	SUM4	0.873 (0.841-0.905)	0.016	0.951 (0.934-0.968)	0.009	0.961 (0.947-0.976)	0.007
	PBF	0.871 (0.838-0.905)	0.017	0.947 (0.928-0.965)	0.009	0.960 (0.944-0.975)	0.008

Note. 95% CI – confidence interval; SE – standard errors; WC – waist circumference: WHtR – waist to height ratio; TrSF – triceps skinfold; BiSF – biceps skinfold; SsSF – subscapular skinfold; AbSF – abdominal skinfold; SUM2 – sum of 2 skinfold; SUM4 – sum of 4 skinfold; PBF – percentage of body fat.

Table III. Optimal cut-off points for each variable based on sex and nutritional status.

Nutr. Status	Variable	Girls						Boys					
		DTC	Sen.	Spe.	YI	Sen.	Spe.	DTC	Sen.	Spe.	YI	Sen.	Spe.
UW	WC	<60.2	81.7	80.5	<61.5	76.6	85.7	<60.3	84.3	76.8	<61.2	80.1	82.1
	WHtR	<0.41	79.2	77.9	<0.42	68.4	92.2	<0.40	85.1	69.6	<0.42	71.3	91.1
	TrSF	<10.2	88.7	63.6	<11.8	79.1	76.6	<9.7	80.4	71.4	<10.4	74.1	82.1
	BiSF	<7.7	76.9	77.9	<8.1	68.9	88.3	<6.1	71.4	78.6	<7.1	62.5	91.1
	SsSF	<6.2	89.3	67.5	<7.4	76.9	88.3	<5.9	86.8	73.2	<6.9	72.0	94.6
	AbSF	<8.7	87.8	71.4	<9.5	83.2	79.2	<7.1	81.2	78.6	<10.5	65.7	94.6
	SUM2	<17.9	88.2	72.7	<18.8	82.7	80.5	<15.5	82.2	80.4	<15.5	82.2	80.4
	SUM4	<32.8	91.0	72.7	<36.1	84.0	81.8	<26.9	86.5	67.9	<37.1	65.2	98.2
	PBF	<17.1	88.2	72.7	<17.9	82.7	80.5	<14.9	82.2	80.4	<14.9	82.2	80.4
OW	WC	>68.8	93.8	73.6	>70.0	88.2	81.6	>69.9	92.9	76.6	>71.3	86.7	86.4
	WHtR	>0.46	93.8	80.8	>0.46	91.0	87.5	>0.45	92.0	84.3	>0.47	88.0	91.0
	TrSF	>15.1	91.7	70.9	>15.1	91.7	70.9	>14.9	88.9	78.3	>16.9	83.1	88.5
	BiSF	>10.4	87.5	70.6	>13.0	76.4	84.4	>9.3	88.9	78.7	>10.6	83.6	84.3
	SsSF	>11.0	95.1	73.3	>12.2	88.9	85.7	>9.1	92	83.9	>9.7	91.6	85.2
	AbSF	>17.3	90.3	72.6	>19.4	82.6	82.7	>15.3	93.3	77	>19.2	84.4	86.9
	SUM2	>27.2	93.1	77.4	>30.8	83.3	88.6	>23.9	93.3	79.7	>27.9	85.8	91.7
	SUM4	>54.0	95.8	73.5	>65.1	85.4	90.0	>52.6	92.4	82.7	>59.9	86.7	90.2
	PBF	>24.0	93.1	77.4	>26.1	83.3	88.6	>21.9	93.3	79.7	>24.6	85.8	91.7
OB	WC	>78.9	92.0	90.8	>78.9	92.0	90.8	>77.8	98.2	82.8	>77.8	98.2	82.8
	WHtR	>0.51	95.8	91.4	>0.51	95.8	91.4	>0.52	98.2	89.7	>0.53	96.4	91.9
	TrSF	>17.8	100	75.0	>19.1	95.8	85.0	>18.9	94.6	80.0	>18.9	94.6	80.0
	BiSF	>14.7	100	84.3	>14.7	100	84.3	>12.9	94.6	79.3	>12.9	94.6	79.3
	SsSF	>17.8	100	89.8	>17.8	100	89.8	>14.9	94.6	86.1	>16.2	92.9	89.4
	AbSF	>24.5	91.7	84.2	>31.5	83.3	93.8	>21.8	98.2	74.2	>22.9	96.4	77.4
	SUM2	>36.9	100	87.7	>36.9	100	87.7	>34.9	96.4	85.4	>39.7	91.1	91.4
	SUM4	>78.1	100	89.4	>78.1	100	89.4	>70.9	100	81.9	>78.8	96.4	86.8
	PBF	>38.6	100	87.7	>38.6	100	87.7	>26.9	98.2	82.5	>40.1	91.1	91.4

Note. UW – underweight; OW – overweight; OB – obesity; DTC – distance to upper left corner; Sen – sensitivity; Spe – specificity; YI – youden index; WC – waist circumference: WHtR – waist to height ratio; TrSF – triceps skinfold; BiSF – biceps skinfold; SsSF – subscapular skinfold; AbSF – abdominal skinfold; SUM2 – sum of 2 skinfold; SUM4 – sum of 4 skinfold; PBF – percentage of body fat

The prevalence of overweight and obesity in boys was higher than in girls (22.7 % vs. 16.4 % for overweight and 7.5 % vs. 3.3 % for obesity), while girls tend to be more underweight (10.5 % vs. 7.5 %) in this specific sample of Montenegrin children (Table IV).

Table IV. Nutritional status and prevalence by IOTF references in children from Montenegro

Sex	Age	Underwei	Normal	Overweig	Obesit
Girls	9	13.5 %	63.9 %	18.0 %	4.5 %
	10	9.8 %	69.5 %	18.3 %	2.4 %
	11	11.5 %	75.6 %	12.2 %	0.6 %
	12	7.9 %	67.6 %	19.4 %	5.0 %
	13	10.0 %	71.4 %	14.3 %	4.3 %
Total Girls		10.5 %	69.8 %	16.4 %	3.3 %
Boys	9	10.9 %	59.9 %	22.4 %	6.8 %
	10	6.9 %	62.1 %	21.3 %	9.8 %
	11	7.4 %	63.7 %	20.0 %	8.9 %
	12	5.4 %	62.2 %	25.0 %	7.4 %
	13	7.0 %	64.1 %	24.6 %	4.2 %
Total Boys		7.5 %	62.3 %	22.7 %	7.5 %

DISCUSSION

This article has two aims: (a) first aim was to determine what is the most applicable and the simplest alternative for recommended BMI categories for underweight, overweight and obesity related to IOTF references, from the practical standpoint; (b) second aim was to determine the prevalence of the nutritional status in Montenegro on this representative sample of school children aged 9-13 years and compare them with peers from relevant and similar studies from both the local region and globally. This research showed that WHtR has the highest discriminative power when the simplicity criterion is used to evaluate the nutritional status. Therefore, WHtR could be used either as the best alternative or as the replacement of the IOTF reference values, which becomes even clearer in the case of OW and OB among Montenegrin children of this age. However, it is important to note that all evaluated methods have demonstrated outstanding or excellent discriminatory power, and potentially could also replace the IOTF references. Last, but not less important, is that the level of OW and OB is quite present in children of this age, especially among boys, while the number of UW children is more prevalent in the girl's group of that age in Montenegro.

The potential advantage of WHtR in relation to other methods is reflected in the fact that it has a greater note of individuality because it involves the subject's height and WC (Ashwell *et al*., 2012). In other words, it was the variable with the least susceptibility to age and maturation that characterises this turbulent period of child development. This advantage is especially important because of the morphological characteristics of the population from Montenegro known as one of the tallest nations globally (Grasgruber *et al*., 2017), so comparing them with available WC references could jeopardise their reliability in this morphologically specific population. Another drawback of the WC is that it is influenced by age and sex (Ashwell *et al*., 2012), and therefore methods, such as the LMS method (Sharma *et al*., 2015) would be more appropriate for defining precise cut-off points related to WC.

The advantage of WHtR over SF thickness is reflected in the simplicity and precision of the measurement because it does not require the use of callipers and the training of the measurer, as well as the calculation of raw data itself in cases where we estimate fat mass, PBF or lean mass. Conversely, WHtR does not have the ability to identify subcutaneous fat distribution, which we found to have the best discriminative power as SF calculations or SF individually (SUM4 in case of girls, and SsSF in the boy's group). On the other side, the selection of cut-off point methodology and estimation formulas may influence the final judgment or misjudgement of nutritional status. More precisely, in the case of PBF Slaughter's formula overestimates PBF in OB subjects of both sexes compared to recommended references (Laurson *et al*., 2011). The optimal cut-off value of PBF for OB girls was 38.6 % by both used cut-point calculation methods, which represents a small overestimation. In the case of boys, a big discrepancy occurred between the used methods, with PBF being slightly underestimated by the DTC method at 26.9 %, while YI highly overestimated PBF cut-off value at 40.1 %, in comparison to the recommended 30 %. Thus, this study suggests the use of individual SF or sum of SF thickness for PBF estimation, especially for OB, rather than formula-based calculation in both genders, while DTC is a better method for defining an optimal cut-off point calculation among boys. In relation to BMI, WHtR and WC are primarily an advantage because they can clearly indicate the presence of abdominal overweight or obesity (Schröder *et al*., 2014). In some cases, BMI can underestimate the muscle mass by classifying muscular children as a risk category, while participants with abdominal obesity and associated risks can be categorised as a risk-free group. In contrast, SF thickness can overcome the disadvantage of BMI, but it is not able to identify visceral fats which are shown to be well estimated by WHtR. Furthermore, only WHtR was not influenced by age, which represents a very important point during the maturation period, especially in countries which do not have developed national references, or they have some specifics related to anthropo-morphological characteristics. Finally, this point could be important for the development of global references for international comparability between children of this age span. Ultimately,it seems that WHtR has the potential for the development of the global standards for estimation of nutritional status, with eventual adjustments to race (i.e. western Asians are shorter with wider bodies) and maturation that belongs to the age range beyond the one we used (i.e. higher rate in growth of longitudinal dimensionalities in puberty).

Following the aforementioned analyses, the study from Southern India suggested the cut-off point for both sexes for OW to be 0.48 (Panjikkaran, 2013), which is lower than recommended 0.5 (Ashwell *et al*., 2012). Comparing to our results even this value would be high because the WHtR cut-off value for girls was 0.46 by both analysed methods, while cut-off values for boys were 0.45 and 0.47 for DFC and YI, respectively (Table III). The study from China identified somewhat lower cut-off values for girls (OW > 0.445; OB > 0.475) and boys (OW > 0.445; OB > 0.485), but the authors used a different anatomic point of WC measurement (2 cm above umbilicus) (Weili *et al*., 2007). Similar WHtR cut-offs to our study were found in a study conducted on Spanish girls and boys (6-14 years old), with cut-offs for OW being 0.47-0.48 and for OB being 0.50 and 0.51 for girls and boys, respectively (Marrodán *et al*., 2013). Each of the mentioned studies, including ours, found that OW cut-off values for WHtR range between 0.44 to 0.48, which is lower than the widely used cut-off value for adults (0.50), indicating that the transversal and longitudinal body proportions of adults differ from the children's and therefore the cut-off points of adults are not appropriate to be used in children of this age.

According to cut-offs adjusted to our sample, the prevalence of OW and OB is high, especially among boys. Conversely, the prevalence of UW was also relatively high, with the rate being higher among girls. In that regards, Martinovic *et al*. (2015) found the prevalence of OW and OB girls 15.6 % and 3.5 % to be very similar to our study, while the prevalence of OW boys was higher by 3.2 % and OB by 0.5 %, with the same trend of boys being more OW and OB than girls. Furthermore, the study conducted on sample of children from the capital city Montenegro (Podgorica) showed that the prevalence of OW (23.5 %) and OB (7.6 %) boys as well as in girls (OW = 21.1 % and OB = 6 %) is quite higher than in our study (Jaksic *et al*., 2017). The two aforementioned studies, together with our findings strongly indicate that rates of OW and OB increases in boys more than in girls, suggesting that boys may be more prone to socio-cultural and/or environmental changes than girls. Comparing to Macedonian children (Myrtaj *et al*., 2018), the results regarding the prevalence of OW (22.7 % vs. 22.1 %) and OB (7.5 % vs. 7.2 %) are quite consistent among boys, while OB and OW was more prevalent in Montenegrin girls (OW = 16.4 % vs.15.5 % and OB = 3.3 % vs. 2.4 %). Generally, OW and OB prevalence was shown to be lower in northern European countries compared to southern ones, among which Montenegro seems to be in the group of countries with higher rates (Lobstein & Frelut, 2003).

According to our knowledge and available data, this is the first study that combined several different anthropometric methods for the estimation of nutritional status and offered cut-off points for children of this age. For a wider application of the offered model and to potentially achieve the status of national references, it should be confirmed on a larger sample of participants and through a longitudinal approach. In addition to the above, the exact date of birth should be included, whereas in our case only the year of birth was available and maturation status is advisable to be defined by a medical practitioner.

CONCLUSION

As a general conclusion, the simplest and most precise solution for the estimation of nutritional status among school-age children in Montenegro according to IOTF references is WHtR. However, the use of both measures, WHtR and BMI would further decrease the possibility of misjudgement in risk assessment. Apart from being the best alternative, WHtR is also a better indicator of body composition itself, because it closely estimates abdominal obesity, while BMI does not have such possibility. The employment of SF thickness measurements could be effectively used in determining the amount of fat and lean tissue and malnutrition. However, it is a complex and time-consuming method that requires training, special tools, and consistency in measurement sites, thus the advantage was given to WHtR due to its high simplicity and informativeness at the same time.

MILASINOVIC, R.; POPOVIC, A.; PETKOVIC, J.; GORANOVIC, K. & JOKSIMOVIC, M. Características antropométricas, composición corporal y estado nutricional de los niños más pequeños de la escuela primaria en Montenegro. Estudio nacional. *Int. J. Morphol., 42(2)*:324-331, 2024.

RESUMEN: Este artículo tiene dos objetivos: (a) el primero fue determinar cuál es la alternativa más aplicable y más sencilla para las categorías de IMC recomendadas para bajo peso, sobrepeso y obesidad relacionadas con las referencias de la IOTF, desde el punto de vista práctico; (b) el segundo objetivo fue determinar la prevalencia del estado nutricional en Montenegro en esta muestra representativa de escolares de 9 a 13 años y compararlos con pares de estudios relevantes y similares tanto de la región local como a nivel mundial. En el estudio participaron 1478 niños sanos de Montenegro divididos en dos submuestras de 732 niñas y 746 niños. De acuerdo con el índice de masa corporal (IMC) de la IOTF, se utilizaron valores de referencia mediante análisis de curvas ROC para evaluar posibles alternativas para la estimación del estado nutricional de esta muestra en niños. Sólo el ICT no mostró diferencias significativas relacionadas con la edad en el caso de ambos sexos. Teniendo en consideración el estado nutricional de los niños, se determinó que los éstos tenían una prevalencia considerablemente mayor de sobrepeso (22,7 % frente a 16,4 %) y obesidad (7,5 % frente a 3,3 %) en comparación con las niñas. Por otro lado, las niñas tenían más prevalencia de bajo peso (10,5 % frente a 7,5 %). El WHtR parece la mejor alternativa para la estimación de la obesidad y el sobrepeso por su sencillez y equipamiento necesario.

PALABRAS CLAVE: Bajo peso; Exceso de peso; Obesidad; Relación cintura-altura; Pliegue cutáneo.

REFERENCES

Ashwell, M.; Gunn, P. & Gibson, S. Waist-to-height ratio is a better screening tool than waist circumference and BMI for adult cardiometabolic risk factors: systematic review and meta-analysis. *Obes. Rev., 13(3)*:275-86, 2012.

Cole, T. J.; Bellizzi, M. C.; Flegal, K. M. & Dietz, W. H. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ, 320(7244)*:1240-3, 2000.

Cole, T. J.; Flegal, K. M.; Nicholls, D. & Jackson, A. A. Body mass index cut offs to define thinness in children and adolescents: international survey. *BMJ, 335*:194, 2007.

Dezenberg, C. V.; Nagy, T. R.; Gower, B. A.; Johnson, R. & Goran, M. I. Predicting body composition from anthropometry in pre-adolescent children. *Int. J. Obes. Relat. Metab. Disord., 23(3)*:253-9, 1999.

Grasgruber, P.; Popovic, S.; Bokuvka, D.; Davidovic, I.; Hrebícková, S.; Ingrová, P.; Potpara, P.; Prce, S. & Stracárová, N. The mountains of giants: an anthropometric survey of male youths in Bosnia and Herzegovina. *R. Soc. Open Sci., 4(4)*:161054, 2017.

Hosmer Jr., D. W.; Lemeshow, S. & Sturdivant, R. X. Applied Logistic Regression. 3rd ed. Hoboken, John Wiley & Sons, 2013.

Hu, F. B. *Obesity Epidemiology*. New York, Oxford University Press, 2008.

Jaksic, M.; Martinovic, M.; Belojevic, G.; Kavaric, N.; Asanin, B.; Samardzic, M. Pantovic, S. & Boljevic, J. Prevalence of and contributing factors to overweight and obesity among the schoolchildren of Podgorica, Montenegro. *Srpski Arhiv Za Celokupno Lekarstvo, 145(1-2)*:20-5, 2017.

Kuczmarski, R. J.; Ogden, C. L.; Grummer-Strawn, L. M.; Flegal, K. M.; Guo, S. S.; Wei, R.; Mei, Z.; Curtin, L. R.; Roche, A. F. & Johnson, C. L. CDC growth charts: United States. *Adv. Data, (314)*:1-27, 2000.

Laurson, K. R., Eisenmann, J. C. & Welk & G. J. Body fat percentile curves for U.S. children and adolescents. *Am. J. Prev. Med., 41(4 Suppl. 2)*:S87-92, 2011.

Lobstein, T. & Frelut, M. L. Prevalence of overweight among children in Europe. *Obes. Rev., 4(4)*:195-200, 2003.

Magalhães, E. I.; Sant'Ana, L. F.; Priore, S. E. & Franceschini, S. C. Waist circumference, waist/height ratio, and neck circumference as parameters of central obesity assessment in children. *Rev. Paul. Pediatr., 32(3)*:273-81, 2014.

Marrodán, M. D.; Martínez-Álvarez, J. R.; González-Montero, M. D. E.; López-Ejeda, N.; Cabañas, M. D. & Prado, C. Diagnostic accuracy of waist to height ratio in screening of overweight and infant obesity. *Med. Clin. (Barc.), 140(7)*:296-301, 2013.

Martinovic, M.; Belojevic, G.; Evans, G. W.; Lausevic, D.; Asanin, B.; Samardzic, M.; Terzic, M.; Pantovic, S.; Jaksic, M. & Boljevic, J. Prevalence of and contributing factors for overweight and obesity among Montenegrin schoolchildren. *Eur. J. Public Health, 25(5)*:833-9, 2015.

Myrtaj, N.; Maliqi, A.; Gontarev, S.; Kalac, R.; Georgiev, G. & Stojanoska, B. B. Anthropometry and body composition of adolescents in Macedonia. *Int. J. Morphol., 36(4)*:1398-406, 2018.

Ng, M.; Fleming, T.; Robinson, M.; Thomson, B.; Graetz, N.; Margono, C.; Mullany, E. C.; Biryukov, S.; Abbafati, C.; Abera, S. F.; *et al*. Global, regional and national prevalence of overweight and obesity in children and adults 1980-2013: A systematic analysis. *Lancet, 384(9945)*:766-81, 2014.

Panjikkaran, S. T. Waist to height ratio for recording the risks of overweight in schoolchildren in Kerala. *Indian Pediatr., 50(5)*:493-5, 2013.

Pescatello, L. S.; Arena, R.; Riebe, D. & Thompson, P. D. ACSM's *Guidelines for Exercise Testing and Prescription*. 9th ed. Philadelphia (PA), Wolters Kluwer/Lippincott Williams & Wilkins, 2014.

Rolland-Cachera, M. F.; Akrout, M. & Péneau, S. *History and Meaning of the Body Mass Index*. Interest of Other Anthropometric Measurements. Brussels, The ECOG's EBook on Child and Adolescent Obesity, European Childhood Obesity Group (ECOG), 2015.

Schröder, H.; Ribas, L.; Koebnick, C.; Funtikova, A.; Gomez, S. F.; Fíto, M.; Perez-Rodrigo, C. & Serra-Majem, L. Prevalence of abdominal obesity in Spanish children and adolescents. Do we need waist circumference measurements in pediatric practice? *PLoS One, 9(1)*:e87549, 2014.

Sharma, A. K.; Metzger, D. L.; Daymont, C.; Hadjiyannakis, S. & Rodd, C. J. LMS tables for waist-circumference and waist-height ratio Z-scores in children aged 5-19 y in NHANES III: association with cardio-metabolic risks. *Pediatr. Res., 78(6)*:723-9, 2015.

Slaughter, M. H.; Lohman, T. G.; Boileau, R. A.; Horswill, C. A.; Stillman, R. J.; Van Loan, M. D. & Bemben, D. A. Skinfold equations for estimation of body fatness in children and youth. *Hum. Biol., 60(5)*:709-23, 1988.

Wang, Y. & Lobstein, T. Worldwide trends in childhood overweight and obesity. *Int. J. Pediatr. Obes., 1(1)*:11-25, 2006.

Weili, Y.; He, B.; Yao, H.; Dai, J.; Cui, J.; Ge, D.; Zheng, Y.; Li, L.; Guo, Y.; Xiao, K.; *et al*. Waist-to-height ratio is an accurate and easier index for evaluating obesity in children and adolescents. *Obesity (Silver Spring), 15(3)*:748-52, 2007.

World Health Organization (WHO). World Obesity Federation. Taking Action on Childhood Obesity. Geneva, World Health Organization, 2018. pp.8.

Correspondig author:
Marko Joksimovic
Faculty of Sport and Physical Education
University of Montenegro
Niksic
MONTENEGRO

E-mail: marko.j@ucg.ac.me