

Using relative handgrip strength to identify sarcopenic obesity in children Aged 7–10 Years

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Abstract:

Over the past decade, the World Health Organization has highlighted the increasing prevalence of childhood overweight and obesity as a major global health concern, further complicated by the occurrence of sarcopenic obesity in children. This study evaluated the predictive capacity of Grip-to-BMI as a marker for sarcopenic obesity risk in children aged 7–10 years. The sample consisted of 3,483 children (1,748 girls and 1,734 boys), stratified by age and sex into four groups. Assessments included standard anthropometry, bioimpedance-based body composition analysis, and handgrip strength measured using a Takei TKK 5101 digital dynamometer. Grip-to-BMI was calculated as the average of left and right handgrip strength (kg) divided by BMI (kg/m²). Discriminatory ability was evaluated using receiver operating characteristic analysis, and optimal cut-off points were derived to maximize sensitivity and specificity. Grip-to-BMI demonstrated high discrimination capacity (AUC>0.8), with the highest sensitivity and specificity in nine-year-old boys (88.64% and 80.44%), and in ten-year-old girls (81.6% and 77.78%). The results confirmed that with age the muscular mass and strength increases in boys, while girls manifest higher muscle-fat ratio compared to those of younger age. The outcomes of the research emphasize the applicability of Grip-to-BMI as a simple and effective tool for early detection and interventions aiming to decrease the sarcopenic obesity risk in children. By enabling earlier identification and timely preventive action, this approach could substantially reduce the likelihood of long-term metabolic and functional complications linked to sarcopenic obesity, while also contributing to improved overall health and well-being across the pediatric population.

Key Words: Grip-to-BMI, muscle-to-fat ratio, pediatric screening, body composition, cut-off values.

Introduction

In the last twenty years, overweight and obesity in children have imposed themselves as one of the leading public health challenges on a global and European level. The importance of this problem is due not only to its increasing presence but also to its long-term consequences on growth, metabolic health, motoric functioning and quality of life in children's and later age. Data indicate that an important part of children's population in Europe suffers from overweight or obesity, which emphasizes the need of early recognition of the risk-bearing phenotypes and of timely preventive initiatives (Nittari et al., 2019). Additionally, data provided by the European Childhood Obesity Surveillance Initiative indicate that the problem is widespread in both sexes, with a high prevalence in children aged six to nine years, which confirms the necessity to systematically monitor the body status even in early school age (Spinelli et al., 2021).

The situation is no less worrying in the regional context. The findings obtained in the Republic of North Macedonia stipulate that overweight and obesity are present in an important part of children's population, whereby boys demonstrate a less favorable profile compared to girls (Raufi & Krstevska Kostadinova, 2022). Such data demonstrate that the problem should not be considered only as a body weight issue, but as a complex biological and functional phenomenon that can manifest itself differently depending on age, sex and environment conditions. This becomes even more prominent in periods of disturbance of the everyday routine, as was the COVID-19 pandemic period, when the increased amount of time spent in front of the screen, the reduced physical activity and the changes in nutrition habits additionally contributed to unfavorable changes in the BMI and the fat component of the children's body (Bartha et al., 2022; Jia et al., 2021; Gündüz et al., 2024).

In the framework of this problem, special attention is to be paid to sarcopenic obesity, i.e. a condition characterized by an unfavorable ratio between muscle mass and the fat component of the body. Although

sarcopenia and sarcopenic obesity were, traditionally and for a long time, related mainly to adult population, contemporary knowledge demonstrates that these conditions can also be observed in children and adolescents, which is a serious alarm from the viewpoint of early prevention and health monitoring (Kim et al., 2016; Wabitsch et al., 2012). The essence of the problem is not only the increased muscle mass, but also the functional misbalance between fat and muscle tissue, whereby the increase of adipous and the decrease of the muscular component can lead to weaker muscular strength, reduced muscular capacity and less favorable metabolic profile in early age (Li et al., 2025; Cauley, 2015; Cruz-Jentoft et al., 2019). The problem is additionally complicated because in some children this condition does not have to be immediately identified by the appearance, although the metabolic disorders can already be present (Fitriliani et al., 2023). If this adverse ratio between the muscle and fat mass persists, it is related to higher risk of insulin resistance, metabolic syndrome and reduced cardiorespiratory fitness later in life (Salton et al., 2022; Benson et al., 2006).

This is exactly the reason why this research was necessary. In practice, especially in a school environment and in primary healthcare, there is a clear need of simple, quick, non-invasive and economical indicators able to early identify children bearing the risk of a disturbed muscle-mass balance. The sophisticated methods of assessment of body composition and muscle component, although of only informative character, are not always easily accessible, nor applicable in routine screening of larger children populations. In that context, the relative hand grip strength, expressed through the Grip-to-BMI relation, stands out as an indicator with a real potential for a widespread application, as it connects the functional muscle force with body mass in a simple and operationally applicable way (Steffl et al., 2017; McCarthy et al., 2014).

The actual level of knowledge indicates that Grip-to-BMI is a promising factor of assessment of the sarcopenic obesity risk in children. Literature describes its connection to muscle-fat ratio (MFR), as well as its potential value in identifying children with disturbed muscle and fat component ratio in the body, while a wider context of handgrip research also emphasizes the need of better standardization and interpretation of this functional indicator (Dodds et al., 2016). Additionally, several recent researches indicate that Grip-to-BMI features an important discriminative capacity in the detection of sarcopenic obesity risk in children and adolescents (Bekolli et al., 2024; Gündüz et al., 2024; Gontarev et al., 2020). Nevertheless, despite these encouraging insights, the number of studies of the populations in South-East Europe is still limited, although it is exactly in this region that lifestyle, the sociocultural habits and the environmental conditions can significantly influence the children's body composition and their functional status. Hence, there is a clear scientific and practical need to additionally confirm the applicability of Grip-to-BMI in children in this region, with special attention to age and sex.

Such approach has a multi-layered practical value. If it is demonstrated that Grip-to BMI surely distinguishes children exposed to higher risk, than it can be used as a screening tool in schools, in systems monitoring the children's growth and development, and in early prevention programs. This would enable for timely recognition of children needing a detailed assessment, individual physical activity, direction towards improvement of muscular force and optimization of body composition. Thus, the benefit of the research is not only theoretical, but also directly applicable in everyday professional practice of physical and health education teachers, of pediatricians, kinesiologists and other health professionals.

This research, directed towards addressing this problem, is conceived as a cross-sectional analytical study, conducted on healthy children, at 7 to 10 years of age, with the purpose of analyzing the applicability of the Grip-to BMI ratio as a practical and scientifically justifiable indicator for early recognition of sarcopenic obesity risk. The discriminatory capacity of the Grip-to BMI indicator was evaluated through a ROC analysis, by calculating the surface beneath the curve (AUC), the sensitivity and specificity, in order to conclude whether this indicator can surely distinguish children under higher risk of a disturbed muscle-mass balance.

Hence, the purpose of this research is to conclude whether Grip-to BMI can surely make it possible to differentiate children exposed to sarcopenic obesity risk. A hypothesis was laid that Grip-to-BMI would show a high discrimination capacity ($AUC > 0.8$) in predicting the risk of sarcopenic obesity in healthy children at 7 to 10 years of age. Such findings can contribute to the development of practical, simple and cost-effective models of school screening and an early prevention of the disturbed muscle-mass balance in the pediatric population.

Methods

Sample of respondents

The research was conducted in a sample of 3,483 respondents, which were divided into two sub-samples, taking into account the gender of the respondents, and the groups consisted of 1,748 girls and 1,734 boys. Then each sub-sample was additionally stratified into four groups of 7 to 10-year-olds, based on the respondents' age and sex. Boys were divided into 362 seven-year-olds, 477 eight-year-olds, 442 nine-year-olds, and 453 ten-year-olds, while the numbers of girls were 417, 478, 460 and 393 informants respectively. The research included only children with good psycho-physical health, regularly attending classes of PE, written consent having previously been obtained from their parents/guardians. Children suffering from chronic diseases, motoric malformations and neuromuscular disorders were excluded from the research. The research was conducted under the ethical principles set out in the Declaration of Helsinki and approved by the institutional Ethics Committee (Number 549, 10.05.2021) Ss. "Cyril and Methodius University" in Skopje. All measurements

were performed during the months of February, March and April 2022, within the framework of physical education classes, under standard school conditions.

Outcome measures

The anthropometric measurements followed the protocols of the International Biological Program. Body weight was measured in underwear, without footwear, using a medical scale, which had a precision of 0.1 kg. On the other hand, body height was measured using a height measurement scale, with the precision of 0.1 cm. Calculation of body mass index (BMI) was carried out using a standard formula of body weight in kg divided by the squared height in meters.

The body composition was assessed by bioelectrical impedance analysis using the Tanita BC-418MA device (Tanita Corp., Tokyo, Japan), single frequency (50 Hz). The instrument used in this study was compared with the DXA method (which is the gold standard) in mixed populations of children and adults and it showed satisfactory measurement characteristics (Pietrobelli et al., 2004). This instrument enables for measurement of the fat mass (FM), the fat-free mass (FFM), and estimated skeletal muscle mass (SMM) for the torso and the limbs. The appendicular skeletal muscle mass (SMMa) was calculated as a sum of the SMM of the upper and lower limbs. The muscle-fat ratio (MFR) was calculated as SMMa divided by FM.

Handgrip strength was measured with a Takei TTK 5101 (Takei Scientific Instruments Co., Ltd) digital dynamometer (range 1–100 kg). Subjects performed the task in a standing position, with their arms at their sides. The dynamometer was adjusted according to hand size. The grip was performed with a maximal isometric effort for a duration of 3 seconds. The average value of both hands was obtained for each subject, expressed in kilograms. Grip-to-BMI was calculated as the mean of the left and right handgrip strength values (kg) divided by BMI (kg/m²).

Sarcopenia risk diagnosis

Given the lack of an established pediatric consensus and the substantial heterogeneity of diagnostic criteria for sarcopenic obesity (Zembura & Matusik, 2022), we applied a previously published child-specific approach based on sex- and age-stratified BMI z-score quintiles and an MFR-derived threshold (McCarthy et al., 2014; Kim et al., 2016). BMI z-scores were divided into five intervals within each sex-by-age stratum. For each interval, the mean and standard deviation of the muscle-to-fat ratio (MFR) were calculated, and the cut-off for sarcopenic obesity risk was defined as an MFR value below 2 SD from the mean of the third BMI quintile (MFR cut-off: mean - 2 SD of MFR for the 3rd BMI quintile). Children with MFR values below this threshold were classified as at risk of sarcopenic obesity. This pragmatic definition is feasible in field settings using BIA and handgrip dynamometry and has been applied in pediatric research.

Statistics and Data Analysis

The normal distribution of all the obtained data was tested using the Kolmogorov-Smirnov test while the Levene test was used to evaluate the homogeneity of the variants. All data were expressed as the arithmetic means $\pm$ the standard deviation, separately for both sexes and the four age groups. The differences between the boys and girls for each of the age groups were determined using independent-samples t-tests. Besides the significance test, the Cohen's d was calculated for each important difference, as a measure of the size of the effect, based on the difference between the average and the total standard deviations.

The correlations between muscle-fat ratio (MFR) and Grip-to-BMI were examined using Pearson's correlation coefficients, stratified by age group and sex. As a sensitivity analysis, Spearman's rank correlations were also computed to confirm the robustness of the observed associations.

ROC-curves were used to estimate the discrimination capacity of the Grip-to-BMI in the prediction of the sarcopenic obesity risk. The value of the areas under the ROC curve (the AUC) was interpreted as follows: 0.90 to 1.00 indicates excellent discrimination ability, the values from 0.80 to 0.89 refer to a good ability, the ability of 0.70 to 0.79 was considered acceptable, the one from 0.60 to 0.69 was poor and the range from 0.50 to 0.59 referred to absence of ability. Youden index was applied in the identification of optimal limit point for each age group and sex ($J = \text{sensitivity} + \text{specificity} - 1$). The ROC direction was designed so that smaller test values suggested more evidence for a positive state (Testpos=Small) because the positive (risk) group had lower Grip-to-BMI. All statistic analyses were conducted with the SPSS (version 26.0) packages and the MedCalc (version 19.1.3) while the $p < 0.05$ was established as a statistic significance level.

Results

Table 1 demonstrates the descriptive statistical parameters and the differences between boys and girls according to their age group, analyzed by means of the independent-samples t-tests. The table review indicates statistically significantly sex differences in several anthropometric, the body composition indicators as well as in the results of the absolute and relative values obtained from the handgrip dynamometry test. In the group of seven-year-olds, boys demonstrated importantly higher values in the following variables: body fat percentage (BFP%, $p < 0.001$), body fat expressed in kilograms (BFM, $p = 0.001$), absolute handgrip strength (HGS, $p < 0.001$), and its relation with BMI (Grip-to-BMI, $p < 0.001$). The Cohen's d values for HGS was 0.52 and Grip-to-BMI were 0.37, indicating a moderate effect of sex on these parameters. In contrast, girls showed a higher muscle-fat ratio (MFR, $p < 0.001$).

At age eight, boys had higher values for percentage muscle mass (SMM, $p < 0.001$), HGS ($p < 0.001$) and Grip-to-BMI ($p < 0.001$), with Cohen's d of 0.52 for HGS and 0.45 for Grip-to-BMI, again indicating a moderate size of influence effect. MFR was higher in girls, but the difference was not statistically significant ($p = 0.975$).

With nine-year-olds, boys exhibited significantly greater values of body weight (BW $p < 0.001$), BMI ($p < 0.001$), BFP ($p < 0.001$), SMM ($p < 0.001$), HGS ($p < 0.001$), and Grip-to-BMI ($p < 0.001$). The value of the Cohen's d effect was 0.56 for HGS and 0.29 for Grip-to-BMI, suggesting a moderate to small scope of impact. MFR did not demonstrate statistically differences related to sex ($p = 0.975$).

In ten-year-old children, boys continued to dominate in the parameters of muscle mass (SMM, $p < 0.001$), HGS ($p < 0.001$) and Grip-to-BMI ($p = 0.014$). Cohen's d in this group was 0.33 for HGS and 0.21 for Grip-to-BMI, indicating small influence effects. When it comes to differences in body weight (BW) and body fat percentage (BFP%), they do not present statistically significant results.

The findings indicate that there are sex-related differences in terms of muscle strength and of strength BMI relation in all age groups, the differences being most prominent in younger age, which indicates the need for an age and sex differentiated approach in the assessment of the risk of a disturbed body composition and functionality in children.

Table 1. Descriptive statistics of boys and girls

Variable	7 Year					8 Year				
	Boys		Girls		Sig	Boys		Girls		Sig
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
BH (cm)	126.94	5.98	126.37	6.05	0.316	132.44	6.27	132.09	6.23	0.480
BW (kg)	29.39	7.18	28.14	5.90	0.046	32.60	8.05	31.95	7.42	0.266
BMI (kg/m ²)	18.08	3.29	17.59	2.88	0.056	18.49	3.51	18.14	3.16	0.249
BMI z	-0.01	0.98	-0.02	1.04	0.629	0.00	1.00	-0.02	0.96	0.969
BFP (%)	23.65	7.79	21.65	7.83	0.001	22.94	7.62	22.47	8.21	0.465
BFM (kg)	7.38	4.23	6.46	3.64	0.001	7.97	4.65	7.69	4.45	0.312
SMM (%)	28.40	2.98	28.60	2.16	0.567	30.49	2.71	29.93	2.10	0.000
SMM (kg)	8.43	2.49	8.07	1.84	0.205	9.99	2.70	9.56	2.24	0.027
LEN (kg)	22.01	3.50	21.68	2.89	0.678	24.64	3.96	24.26	3.45	0.260
MFR (kg/kg)	1.36	0.56	1.54	0.70	0.000	1.51	0.64	1.59	0.80	0.975
HGS (kg)	11.77	2.48	10.55	2.18	0.000	13.46	2.91	12.02	2.59	0.000
Grip-to-BMI	0.66	0.14	0.61	0.13	0.000	0.74	0.16	0.67	0.15	0.000

Table 1. (continued). Descriptive statistics of boys and girls.

Variable	9 Year					10 Year				
	Boys		Girls		Sig	Boys		Girls		Sig
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
BH (cm)	138.07	6.82	137.22	6.92	0.100	143.81	7.22	144.38	7.61	0.451
BW (kg)	37.88	9.40	35.52	9.01	0.000	42.39	11.21	41.62	10.46	0.492
BMI (kg/m ²)	19.70	3.74	18.67	3.57	0.000	20.23	4.03	19.73	3.80	0.097
BMI z	0.00	1.00	0.00	1.00	0.980	-0.02	0.92	0.00	1.00	0.946
BFP (%)	24.76	7.95	23.07	8.56	0.000	24.66	8.11	24.48	8.46	0.661
BFM (kg)	9.99	5.40	8.83	5.31	0.000	11.21	6.28	10.88	6.03	0.533
SMM (%)	31.66	2.45	30.83	2.19	0.000	32.86	2.31	31.86	2.33	0.000
SMM (kg)	12.00	3.07	10.91	2.65	0.000	13.89	3.54	13.18	3.05	0.005
LEN (kg)	27.89	4.60	26.69	4.28	0.000	31.18	5.53	30.74	5.37	0.247
MFR (kg/kg)	1.46	0.60	1.61	0.82	0.070	1.55	0.75	1.53	0.75	0.476
HGS (kg)	15.38	3.07	13.72	2.90	0.000	17.20	3.52	16.06	3.33	0.000
Grip-to-BMI	0.80	0.17	0.75	0.17	0.000	0.87	0.19	0.83	0.19	0.014

Note. Values are presented as mean $\pm$ standard deviation. p values were derived from independent-samples t -tests. Comparing boys and girls within each age group.

Table 2. Pearson and Spearman correlations between muscle-to-fat ratio (MFR) and Grip-to-BMI, by age and sex.

	Years	MFR		Girls	
		Boys			
		r	ρ	r	ρ
Grip-to-BMI	7 year	.523**	.603**	.380**	.479**
	8 year	.488**	.534**	.474**	.536**
	9 year	.563**	.627**	.490**	.580**
	10 year	.541**	.644**	.584**	.650**
	Total	.514**	.568**	.433**	.484**

Note. r = Pearson correlation coefficient; ρ = Spearman rank correlation coefficient. Grip-to-BMI = handgrip strength-to-body mass index ratio. ** $p < 0.01$.

What can be seen from the overview in Table 2 is a significantly positive correlation between the muscle-fat ratio (MFR) and Grip-to-BMI in both boys and girls of all age groups ($p < 0.01$). In boys, the correlation varies from $r = 0.534$ (eight-year-olds) to $r = 0.644$ (ten-year-olds), the total correlation amounting $r = 0.568$, indicating moderate to strong connection. In girls, the values vary from $r = 0.479$ (seven-year-olds) to $r = 0.650$ (ten-year-olds), the total correlation being $r = 0.484$. The relation is stronger in ten-year-old children of both sexes, which emphasizes the importance of the Grip-to-BMI as a practical indicator for the assessment of body composition, especially in older children.

Table 3. Prevalence of children classified as at risk of sarcopenic obesity by age and sex.

Years	Boys		Girls	
	f	%	f	%
7 year	48	13.30%	91	22.10%
8 year	75	15.70%	73	15.30%
9 year	61	13.80%	42	9.10%
10 year	44	9.70%	60	15.50%

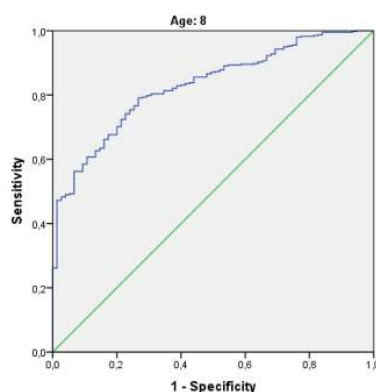
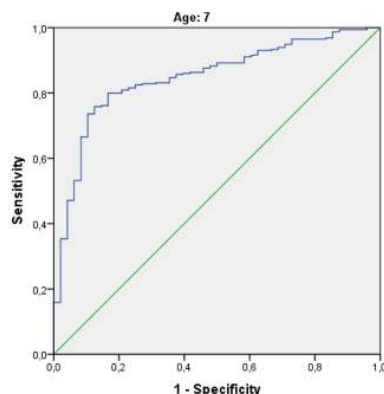
The prevalence rate (Table 3) for boys categorized as at risk for sarcopenic obesity was highest at the age of 8 (15.7%), and it kept declining to 13.8% and 9.7% at ages 9 and 10, respectively. The prevalence rate for girls was highest at the age of 7 (22.1%), and it kept declining to 9.1% at age 9, then escalated to 15.5% at age 10.

The statistic analysis (Table 4) of the ROC analysis data demonstrate that the Grip-to-BMI which is an important indicator for the evaluation of the sarcopenic obesity risk in all children aged 7 to 10 years. The AUC (Area Under the Curve) values in boys vary from 0.828 to 0.885 and from 0.809 to 0.862 in girls, indicating that the relative grip force has a very good discrimination capacity in the prediction of sarcopenic obesity in both sexes. The limit values gradually increase with age, reflecting the increased importance of the relative force as opposed to body mass. The sensitivity is the highest in 9-year old boys (88.64%) and in 7-year-old girls (91.21%), while the specificity reaches its maximum in 9-year-old boys (80.44%) and 10-year-old girls (77.78%). The Youden index (J), represented the equilibrium between sensitivity and specificity, reaches its peak in 10-year-old boys (0.691) and nine-year-old girls (0.649), which emphasizes the optimal efficiency of the method. The obtained results confirm the applicability of the Grip-to-BMI as a simple, non-invasive and practical indicator for the early identification of the sarcopenic obesity risk in the pediatric population, enabling for potential intervention before the development of serious consequences.

Table 4. Receiver operating characteristic evaluation of handgrip strength-to-body mass index ratio, by age and sex.

Years	AUC (95% CI)	p- Value	Cut-off point	Sensitivity	Specificity	Youden index J
Boys						
7 year	0.847 (0.806 to 0.883)	<0.001	0.590	87.50	75.80	0.633
8 year	0.828 (0.792 to 0.861)	<0.001	0.646	73.33	79.10	0.524
9 year	0.866 (0.830 to 0.896)	<0.001	0.726	86.89	72.44	0.593
10 year	0.885 (0.852 to 0.913)	<0.001	0.747	88.64	80.44	0.691
Girls						
7 year	0.819 (0.779 to 0.855)	<0.001	0.606	91.21	61.04	0.523
8 year	0.809 (0.771 to 0.843)	<0.001	0.593	76.71	76.05	0.528
9 year	0.849 (0.813 to 0.881)	<0.001	0.659	90.48	74.40	0.649
10 year	0.862 (0.824 to 0.894)	<0.001	0.741	81.67	77.78	0.595

Note. AUC = area under the curve; CI = confidence interval. Cut-off values refer to the handgrip strength-to-body mass index ratio.



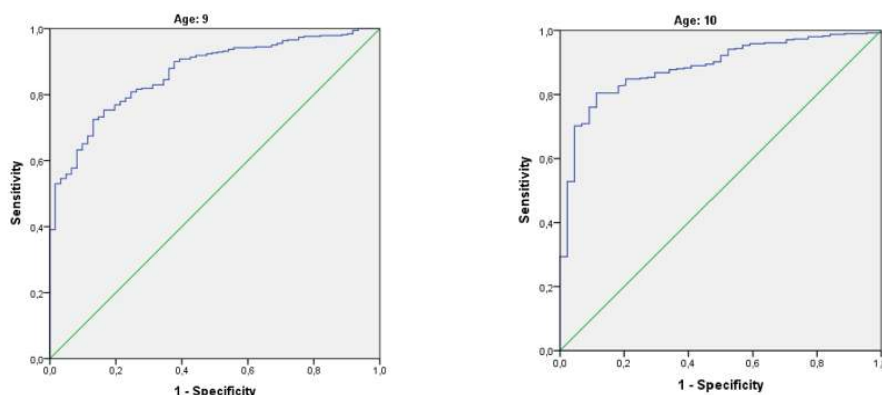


Figure 1. Receiver-operating characteristic curve of Grip-to-BMI in boys ($p < 0.001$)

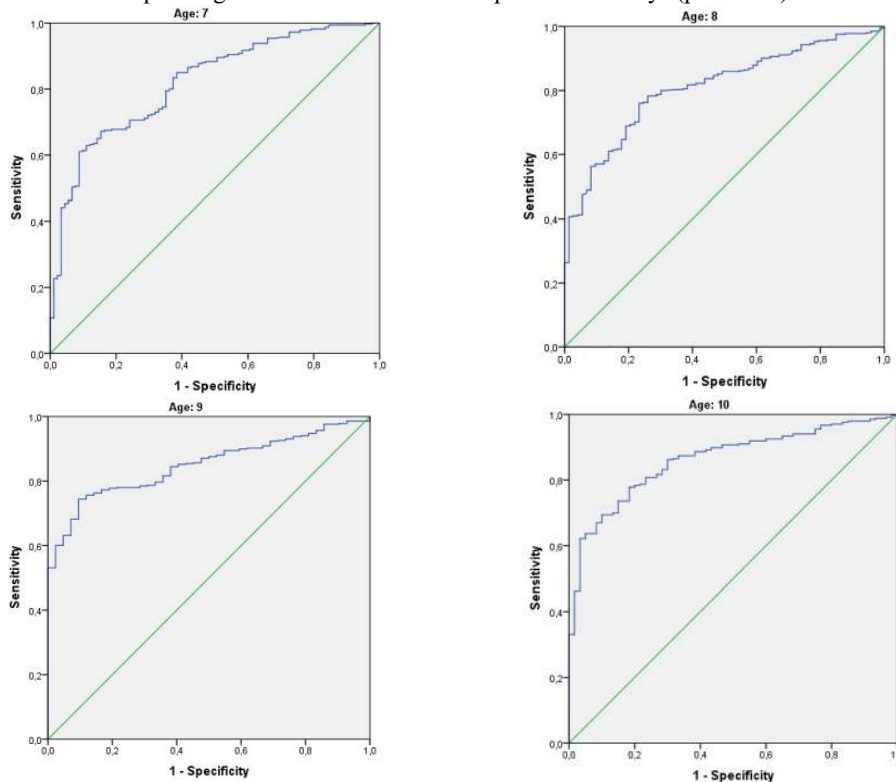


Figure 2. Receiver-operating characteristic curve of Grip-to-BMI in girls ($p < 0.001$)

Discussion

The results of our study clearly demonstrate that the differences related to anthropometric indicators, body composition and muscle strength between boys and girls become ever more pronounced with the increase in age. The absolute and relative handgrip strength (HGS and Grip-to-BMI) in boys show a significant increase, especially in the ninth and tenth years of life, while girls in the younger age groups have a higher muscle-fat ratio (MFR). These results confirm the basic hypothesis of the research: that the sex-specific developmental trajectories significantly affect the distribution of muscle strength and body composition even in the early school age. These differences can be explained by sex-specific growth and development patterns, as well as by the hormonal changes in boys in the prepubertal period, which contribute to the continuous increase in muscle mass and strength (Steffl et al., 2017). Similar patterns have also been documented in the previous studies, whereby Research of this type has been identified by the European Working Group on Sarcopenia, which emphasizes that sex differences in muscle mass and function are present throughout the entire life cycle (Cruz-Jentoft et al., 2019). The Grip-to-BMI indicator that was analyzed through ROC curves, demonstrated high discrimination capacity for the identification of the sarcopenic obesity risk in children population, with AUC values greater than 0.8 in all age groups. The established limit values of the Grip-to-BMI relation indicate a clear tendency to increase with age, from 0.590 in the youngest to 0.747 in the oldest boys, i.e. from 0.606 to 0.741 in girls. This result demonstrates that the interpretation of Grip-to-BMI must be age- and sex-specific, which additionally emphasizes the need of the development of normative referential values for the pediatric population. Our results comply with previous researches, which confirm the validity and the practical applicability of Grip-to-BMI as a

reliable screening tool for the evaluation of the muscular functionality and the health risk in children (Dodds et al., 2016).

Support to these findings is provided by studies conducted on larger populations. Thus, good discrimination capacity of Grip-to-BMI has been reported about the Macedonian children in the prediction of sarcopenic obesity with AUC of 0.771 in girls and 0.843 in boys (Gontarev et al., 2020). Comparable outcomes were also found in the pediatric population in the Czech Republic, in which the range of the AUC values varied from 0.719 to 0.896, depending on age and sex, as reported by Steffl et al. in 2017. Moreover, in the case of adolescent girls, Grip-to-BMI is recognized as a significant indicator for identifying those persons at a greater risk of having sarcopenic obesity, with AUC = 0.816, as reported by Bekolli et al. in 2024, whereas the most recent findings by Gündüz et al. in 2024 report a remarkably high level of diagnostic accuracy, AUC = 0.957, in children aged nine to ten years. This indicates that exactly this age period can represent a sensitive window for early detection and intervention.

The observed association between MFR and relative handgrip strength likely reflects the interplay between muscle quantity/quality and metabolic health. Skeletal muscle is one of the major regions for glucose uptake and lipid oxidation; hence, a relative low muscle mass may contribute to poor insulin sensitivity and poor metabolic health (Muio et al., 2008; Hawley & Lessard, 2008). In line with the above explanation, low muscle mass and muscle strength have been associated with poor insulin resistance and poor metabolic risk among children and adolescents (Jung et al., 2022; Li et al., 2025).

From the practical and public health viewpoint, these results emphasize the need of early identification of children exposed to risk of sarcopenic obesity, especially in environments where the access to more complex diagnostic methods is limited. In this context, Grip-to-BMI stands out as a cost-effective, non-invasive and easily applicable tool for the screening of the functional muscular capacity related to body weight, with the potential to be used in school and primary healthcare programs. The integration of such indicators into the population-screening programs can contribute to early stratification of the risk and directing preventive interventions. Notwithstanding these positive results, a number of study limitations should be mentioned. Firstly, a cross-sectional study does not allow for causal inference or evaluation of intra-child changes during growth and development. Second, body composition was assessed by BIA, which is sensitive to hydration status and may be less precise than reference methods such as DXA; therefore, some degree of misclassification in MFR-derived risk categories cannot be excluded. Lastly, the proposed Grip-to-BMI cut-offs are region-specific. They should therefore be validated in other pediatric populations. As such, Grip-to-BMI should not be considered a definitive diagnostic criterion for assessing the risk of sarcopenic obesity. The future researches should be directed towards the implementation of longitudinal studies in order to follow the changes in Grip-to-BMI and MFR through different stages of growth and biological maturity, which would enable for better understanding of their prognostic value. Furthermore, it is recommendable to include the golden standards in the assessment of the body composition (DXA or MRI) for additional validation of the proposed indicators. Also, the future studies should examine the sensitivity of Grip-to-BMI to interventions directed to the increase of physical activity and the muscular force, as well as its applicability in diverse sociocultural and ethnic contexts. Such approach shall enable for further standardization and wider implementation of this indicator in the pediatric preventive medicine and public healthcare.

Conclusions

The results of this research indicate that the relation between the hand grip strength and the body mass index (Grip-to-BMI) is a valid, simple and non-invasive indicator for early identification of children exposed to increased risk of sarcopenic obesity. Its high discriminatory capacity in all analyzed age groups and in both sexes, indicates that this indicator appropriately reflects the relation between muscle force and body mass in early school age. Also, the established limit values, specific according to age and sex, confirm the need of a differentiated approach in the assessment of risk in children population.

The scientific and practical value of this paper is reflected in the fact that Grip-to BMI is affirmed as a functional indicator of a disturbed muscle-mass balance in children, and as an approach that can be applied in school environment, in pediatric practice and in primary health protection. Being a quick, economical and easily applicable tool, this indicator can contribute to early recognition of children with unfavorable muscle-mass profile and to timely direction towards preventive and corrective interventions. Hence, Grip-to-BMI has a potential to become a useful part of the contemporary models of pediatric screening and improvement of children's health. The upcoming researches should be directed towards a validation of the suggested limit values in other populations and towards the evaluation of their prognostic value during growth and maturation.

Use of Generative AI statement

During the preparation of this work, the authors used ChatGPT (OpenAI) in order to improve language clarity, grammar, and academic phrasing. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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References:

- Bartha, K. O., Csengeri, L., Lichthammer, A., Erdélyi, A., Kubányi, J., & Szűcs, Z. (2022). Impact of the first COVID-19 lockdown on the lifestyle of elementary school children. *Acta Alimentaria*, 51(2), 243–251. <https://doi.org/10.1556/066.2022.00027>
- Bekolli, L., Ramadani, L., Ramabaja, Q., Rashiti, N., Bjelica, D., Gontarev, S., & Morina, B. (2024). Using the relative handgrip strength in identification of the under-aged female candidates exposed to risk of sarcopenic obesity. *Sport Mont*, 22(2), 77–83. <https://doi.org/10.26773/smj.240711>
- Benson, A. C., Torode, M. E., & Fiatarone Singh, M. A. (2006). Muscular strength and cardiorespiratory fitness are associated with higher insulin sensitivity in children and adolescents. *International Journal of Pediatric Obesity*, 1(4), 222–231. <https://doi.org/10.1080/17477160600962864>
- Cauley, J. A. (2015). An overview of sarcopenic obesity. *Journal of Clinical Densitometry*, 18(4), 499–505. <https://doi.org/10.1016/j.jocd.2015.04.013>
- Cruz-Jentoft, A. J., Bahat, G., Bauer, J., Boirie, Y., Bruyère, O., Cederholm, T., Cooper, C., Landi, F., Rolland, Y., Sayer, A. A., Schneider, S. M., Sieber, C. C., Topinkova, E., Vandewoude, M., Visser, M., Zamboni, M., & Writing Group for the European Working Group on Sarcopenia in Older People 2 (EWGSOP2) and the Extended Group for EWGSOP2. (2019). Sarcopenia: Revised European consensus on definition and diagnosis. *Age and Ageing*, 48(1), 16–31. <https://doi.org/10.1093/ageing/afy169>
- Dodds, R. M., Syddall, H. E., Cooper, R., Kuh, D., Cooper, C., & Sayer, A. A. (2016). Global variation in grip strength: A systematic review and meta-analysis. *Age and Ageing*, 45(2), 209–216. <https://doi.org/10.1093/ageing/afv192>
- Fitriliani, A., Pramesona, B. A., & Nareswari, S. (2023). Obesity in children: Long-term causes and consequences. *Medula*, 13(1), 104–109. <https://doi.org/10.53089/medula.v13i1.605>
- Gontarev, S., Jakimovski, M., & Georgiev, G. (2020). Using relative handgrip strength to identify children at risk of sarcopenic obesity. *Nutrición Hospitalaria*, 37(3), 490–496. <https://doi.org/10.20960/nh.02977>
- Hawley, J. A., & Lessard, S. J. (2008). Exercise training-induced improvements in insulin action. *Acta Physiologica*, 192(1), 127–135. <https://doi.org/10.1111/j.1748-1716.2007.01783.x>
- Jia, P., Zhang, L., Yu, W., Yu, B., Liu, M., Zhang, D., & Yang, S. (2021). Impact of COVID-19 lockdown on activity patterns and weight status among youths in China. *International Journal of Obesity*, 45(3), 695–699. <https://doi.org/10.1038/s41366-020-00710-4>
- Jung, H. W., Lee, J., & Kim, J. (2022). Handgrip strength is associated with metabolic syndrome and insulin resistance in children and adolescents. *Journal of Obesity & Metabolic Syndrome*, 31(4), 334–341. <https://doi.org/10.7570/jomes21068>
- Kim, K., Hong, S., & Kim, E. Y. (2016). Reference values of skeletal muscle mass for Korean children and adolescents. *PLoS ONE*, 11(4), e0153383. <https://doi.org/10.1371/journal.pone.0153383>
- Li, Z., Wu, C., Song, Y., Li, Y., Zhao, X., Shang, Y., Zheng, R., Su, H., Su, Q., Li, Y., Fu, R., Lu, W., Xiong, J., & Su, Z. (2025). Weight-specific grip strength as a novel indicator associated with cardiometabolic risk in children: The EMSNGS study. *The Journal of Clinical Endocrinology & Metabolism*, 110(3), 624–633. <https://doi.org/10.1210/clinem/dgae673>
- McCarthy, H. D., Samani-Radia, D., Jebb, S. A., & Prentice, A. M. (2014). Skeletal muscle mass reference curves for children and adolescents. *Pediatric Obesity*, 9(4), 249–259. <https://doi.org/10.1111/j.2047-6310.2013.00168.x>
- Muoio, D. M., Koves, T. R., An, J., & Newgard, C. B. (2008). Metabolic mechanisms of muscle insulin resistance. In M. N. Feinglos & M. A. Bethel (Eds.), *Type 2 diabetes mellitus: An evidence-based approach to practical management* (pp. 35–47). Humana Press. https://doi.org/10.1007/978-1-60327-043-4_3
- Nittari, G., Scuri, S., Petrelli, F., Pirillo, I., Di Luca, N. M., & Grappasonni, I. (2019). Fighting obesity in children from European World Health Organization member states: Epidemiological data, medical-social aspects, and prevention programs. *Clin Ter*, 170(3), e223–e230. <https://doi.org/10.7417/CT.2019.2137>
- Öztelcan Gündüz, B., Duyan Çamurdan, A., Yıldız, M., Baran Aksakal, F. N., & Ünsal, E. N. (2024). Assessing sarcopenic obesity risk in children during the COVID-19 pandemic: Grip-to-BMI ratio. *Medical Research Reports*, 7(1), 18–33. <https://doi.org/10.55517/mrr.1374119>
- Pietrobelli, A., Rubiano, F., St-Onge, M. P., & Heymsfield, S. B. (2004). New bioimpedance analysis system: improved phenotyping with whole-body analysis. *European journal of clinical nutrition*, 58(11), 1479.
- Raufi, A., & Krstevska Konstantinova, M. (2022). Prevalence of overweight and obesity in children: Variation in different ethnicities, age, and sex in North Macedonia. *Pril (Makedon Akad Nauk Umet Odd Med Nauki)*, 43(2), 23–31. <https://doi.org/10.2478/prilozi-2022-0015>
- Salton, N., Kern, S., Interator, H., Lopez, A., Moran-Lev, H., Lebenthal, Y., Ben-Ami, M., Lavie, E., Phillip, M., & Gat-Yablonski, G. (2022). Muscle-to-fat ratio for predicting metabolic syndrome components in children with overweight and obesity. *Child Obesity*, 18(2), 132–142. <https://doi.org/10.1089/chi.2021.0157>
- Spinelli, A., Buoncristiano, M., Nardone, P., Starc, G., Hejgaard, T., Júlíusson, P. B., et al. (2021). Thinness, overweight, and obesity in 6- to 9-year-old children from 36 countries: The World Health Organization European Childhood Obesity Surveillance Initiative—COSI 2015–2017. *Obesity Reviews*, 22(Suppl 6), e13214. <https://doi.org/10.1111/obr.13214>

- Steffl, M., Chrudimský, J., & Tufano, J. J. (2017). Using relative handgrip strength to identify children at risk of sarcopenic obesity. *PLOS ONE*, 12(5), e0177006. <https://doi.org/10.1371/journal.pone.0177006>
- Wabitsch, M., Moss, A., Denzer, C., & Fischer-Posovszky, P. (2012). Das metabolische Syndrom. *Monatsschrift Kinderheilkunde*, 160, 277–292. <https://doi.org/10.1007/s00112-012-2623-7>.
- Zembura, M., & Matusik, P. (2022). Sarcopenic obesity in children and adolescents: a systematic review. *Frontiers in endocrinology*, 13, 914740.