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Using the Relative Handgrip Strength in Identification of the Under-Aged of Female Gender Candidates Exposed at Risk in Developing of Sarcopenic Obesity

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Abstract

Detecting children and minors who are at risk of developing childhood sarcopenic obesity frequently necessitates the use of specialized equipment and costly testing procedures. Finding more affordable and efficient techniques would be extremely advantageous, particularly if they are applicable in various field environments. The aim of this research was to investigate if a comprehensive evaluation of hand grip strength relative to BMI could distinguish young female candidates who may be at risk of developing second-class sarcopenic obesity. The study involved 535 female participants chosen at random from 9 elementary schools in the Skopje region of the Republic N. Macedonia. Several anthropometric measures, body composition measures, and absolute and relative handgrip strength were utilized to achieve the research goals based on the definition of sarcopenic obesity. Bioelectrical impedance was used to determine the percentage of body fat and skeletal muscle mass, with the skeletal muscle mass to fat ratio being calculated. Considering the relative handgrip strength in predicting a sarcopenic obesity class II in female candidates the area under the curve was 0.816. Relative handgrip strength (RHGS kg/kg/m2) is a useful indicator for identifying sarcopenic obesity in young females and can be valuable for guiding health interventions.

Keywords: *bioelectrical impedance, muscle mass, ratio of skeletal muscle mass*

Introduction

Continuous monitoring of health and fitness throughout one's life is crucial, particularly for early detection and treatment of diseases (Henriksson et al., 2019; Ortega et al., 2008). Health examinations that are thorough can be costly and necessitate specific equipment and skilled personnel that are typically found only in medical facilities. Alternatively, field fitness tests are cost-effective, convenient, and enable the assessment of the physical attributes of a large number of individuals quickly (Marques et al., 2021).

For instance, the handgrip test is a key component in various international and national physical fitness assessment tests (Bianco et al., 2015; Marques et al., 2021), as it provides a quick way to evaluate overall muscle strength (Wind et al., 2010), and is linked to several medical conditions across different age brackets. More precisely, inadequate handgrip strength is linked to higher metabolic risk in childrenand (Cohen et al., 2014), other cardio metabolic risk factors in adults and the elderly (Peterson et al., 2016), and is also connected to various aspects of physical fitness (Matsudo et al., 2015).

Rosenberg (1989) explains that sarcopenia develops due to a decline in muscle mass and strength related to aging, typically appearing in later stages of aging. Although sarcopenia is typically seen in the elderly population, new research suggests

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that children and adolescents can also experience this condition (Biolo et al., 2014). Despite the fact that children and adolescents may have limited muscle mass, the rise in obesity, which has become a global epidemic, is a significant problem (Katanic et al., 2023; Lobstein et al., 2004).

It is unclear in children and adolescents whether the absence of muscle mass leads to obesity or if it is the other way around. However, previous studies suggest that obesity may play a role in the development of sarcopenia, leading to the condition known as "sarcopenic obesity" (Cauley, 2015).

Sarcopenic obesity occurs when there is an imbalance between the fat-free mass and fat mass in the body (Cauley, 2015; Stenholm et al., 2008). Sarcopenic obesity is characterized by an imbalance between muscle mass and adipose tissue, which is commonly seen in children rather than the progressive loss of muscle mass typically seen in the elderly with sarcopenia (Fielding et al., 2011; Morley et al., 2014). Children and adolescents who do not look obese on the outside may still have less muscle mass compared to their peers, possibly due to having a high amount of body fat, giving the illusion of a normal or healthy appearance. This creates challenges in identifying children who may have sarcopenic obesity. Having a diagnostic tool to identify children and adolescents with sarcopenic obesity is extremely important. Neglecting to treat any diseases in children that can impact their future health is detrimenta (Gontarev et al., 2020; Steffl et al., 2017).

Due to the varying rates at which children mature and develop, it may be more suitable to use relative measures, as they can be more easily applied to both genders in different developmental stages, rather than absolute measures derived from fitness assessments. Hence, McCarthy and colleagues (2014) indicates that skeletal muscle mass together with the body fat component, i.e. calculating their ratio (MFR), can serve as an indicator of metabolic risk in children. Park et al. (2013) were the first to propose the ratio between muscle mass and fat components to determine the association between muscle mass and metabolic syndrome, but McCarthy et al. (2014) took an additional step and proposed a method to calculate limit values in children using the body mass index together with the ratio of skeletal muscle mass and the fat component. Kim and colleagues (2016), utilized the McCarthy method to detect sarcopenia obesity in children. Regrettably, accurately determining skeletal muscle mass and fat component ratio depends on costly body composition measurements, posing a challenge when assessing a large group of individuals. Nevertheless, in clinical settings, assessing muscle strength rather than skeletal muscle mass is commonly utilized for diagnosing sarcopenia. Cruz-Jentoft et al. (2010) suggested the handgrip dynamometry test as a diagnostic indicator for sarcopenia. Handgrip strength is a quick and easy method to measure in field research, in comparison to techniques like dual energy X-ray absorptiometry and bioelectrical impedance Considering the developmental changes in children's maturational and body size, it is recommended that handgrip strength be measured in relative terms. It is suggested to use the handgrip-to-BMI ratio as a way to measure handgrip strength relative to body size, by dividing the handgrip dynamometry test result by the body mass index. The grip strength relative to body mass index (BMI), also known as the grip-to-BMI ratio, is suggested as a method to identify sarcopenia in the elderly population (McLean et al., 2014).

While the correlation between a lower fat-free component and a higher grip-to-BMI ratio (McLean et al., 2014) has been confirmed in older individuals, there is limited research on this association in adolescents in scientific literature.

The aim of this study is to explore the connection between skeletal muscle mass ratio and fat component (MFR) and relative handgrip strength. The goal is to determine if relative handgrip strength can be used as a substitute for skeletal muscle mass ratio and fat component (MFR) in identifying under-aged females who may be at risk of sarcopenic obesity

Methods

Participants

The study involved 535 female participants selected randomly from various primary schools in the Skopje region. Their average age was 12.47 (±1.1) years old. The research involved students whose parents consented to participate and who were physically and mentally healthy, and regularly attended physical education classes. Candidates of this type were dealt with in compliance with the Helsinki Declaration (revision of Edinburgh 2000). The protocols were approved by the Ethics Committee (Number 549, 10.05.2021) at the Ss. Cyril and Methodius University of Skopje.

Anthropometric measurements

Measurements of the anthropometric characteristics were conducted following the standard procedures of the International Biological Program (Weiner & Lourie, 1969), Anthropometric Standardization Reference Manual (Lohman, Roche, & Martorell, 1988) and Weiner-Lurie (1981). The weight was measured using a Tanita BC-418MA scale (Tanita Corporation, Tokyo, Japan), to the nearest 0.1 kg, with the participant wearing underwear and no shoes. Height was measured without shoes using Martin's anthropometry tool, to the nearest 0.1 cm, in the Frankfort horizontal plane. Body mass index is determined by dividing body weight in kilograms by the square of height in meters [BMI = weight (kg)/height (m)^2].

Components of body composition

Body mass and estimated body composition were assessed using the Tanita BC-418MA single-frequency (50 Hz) segmental Body Composition Analyzer (Tanita Corporation, Tokyo, Japan) with adjustments made for light indoor clothing. The subject was asked to stand barefoot on the analyzer and hold a pair of handgrips, one in each hand, as part of the measurement procedure. It took approximately 30 seconds per subject to complete the BIA component of the measurements. The BIA monitor used in this study provided individual measures of body fat mass (FM) and fat-free mass (FFM), as well as predicted skeletal muscle mass (SMM) in the limbs and trunk. The sum of SMM in the four limbs was also calculated as appendicular skeletal muscle mass (SMMa).

Measurements of segmental electrical properties such as resistance, reactance, and impedance were utilized to assess skeletal muscle mass in the limbs. The predictive equations were used to determine appendicular lean soft tissue, which comprises mostly of skeletal muscle. The impedance device used in this study was tested against DXA in various populations of children and adults, and was found to be superior to previous BIA methods (Pietrobelli et al. 2004).

The Tanita BC418MA model was validated in pediatric population against DXA and air-displacement plethysmography (BodPod Life Measurement, Inc, Concord, CA, USA). Once again, the results showed a strong correlation with the DXA, and there was no significant difference in mean values. The latest research found that the daily variation in limb SMM was less than 1%, which is consistent with previous findings (Pietrobelli et al., 2004).

Handgrip strength

We utilized the Takei TKK 5101 dynamometer from Takei Scientific Instruments Co. Tokyo, Japan. Handgrip strength was measured for both hands using a dynamometer with a range of 1-100 kg. The participant holds the dynamometer in the hand that is being tested, with the arm bent at a 90-degree angle and the elbow next to the body. Once prepared, the candidate (participant) exerts maximum isometric force by squeezing the dynamometer for approximately 3 seconds. However, the subject must not engage in any other body movements and should be strongly motivated to exert their fullest effort. In this case, the highest value obtained from either the right or left hand was chosen as the maximum handgrip strength value. The grip-to BMI ratio was determined by dividing maximal handgrip strength by the BMI.

Sarcopenia risk diagnostics

Female participants were divided into quintiles of the BMI z-score, and the mean and standard deviation of MFR were calculated for each quintile. Cut-off values were determined based on the mean and standard deviation of the MFR for the third BMI quintile. The mean value minus 2 standard deviations of the MFR for the third BMI quintile was used as the cutoff value, and the percentage of sarcopenic obesity individuals was analyzed (Kim et al., 2016; McCarthy et al., 2014).

Statistics and Data Analysis

ROC analyses were conducted to compare the predictive accuracy and determine the best cut-off points (Akobeng, 2007). Pearson product-moment correlations were utilized to examine the relationships between the MFR and grip strength with BMI. The sensitivity and specificity measures based on grip-to-BMI ratio cut-points were used to plot the ROC curves. A diagnostic test with an AUC value of 1 is completely accurate, while another test with a value of 0.5 has no ability to distinguish between different groups (Krzanowski & Hand 2009; Pintea & Moldovan, 2009).The values that resulted in the highest AUC from the ROC curves were indicative of optimal sensitivity and specificity. Using a binary logistic regression model adjusted for age, the probability of developing sarcopenic obesity based on MFR was estimated in individuals at risk of sarcopenic obesity according to the cutoff values of grip-to-BMI. Similarly, a binary logistic regression model adjusted for age was used to calculate the probability of developing sarcopenic obesity based on MFR in subjects considered at risk of sarcopenic obesity using cutoff values in grip-to-BMI. Effect sizes were presented as odds ratios (OR), i.e., exponentiated estimates. All analyses were conducted using the Statistical Package for Social Sciences software (SPSS, v. 26.0 for Windows; SPSS Inc., Chicago, IL, USA) and MedCalc (Version 19.1.3).

Results

In Table 1, the essential descriptive statistical parameters of anthropometric measurements for body mass, both absolute and relative values obtained from the handgrip dynamometry test are presented for the candidates mentioned above.

Table 2 displays the MFR ratio based on BMI z scores quintiles in girls, showing the relationship between skeletal muscle mass and fat component. After reviewing table 2, it is evident that the cut-off value for sarcopenia obesity in girls was 0.860, calculated as the average of the MFR minus 2 standard deviations for the 3rd quintile of BMI. Furthermore, 11.1% of girls fell below this cut-off value. There were no girls with sarcopenia obesity in the first quintile compared to those without it. The second quintile has 0.0%, the third quintile has 0.0%, the fourth quintile has 5.9%, and the fifth quintile has 50.0%. The cutoff values for sarcopenia grade I were determined by calculating the arithmetic mean of the MFR - 1SD for the 3rd quintile of the BMI. In girls, the cutoff value was found to be 1.130, resulting in a sarcopenia grade I proportion of 30.3%. The percentage of girls with grade I sarcopenia compared to those without it was 0.0% in the first quintile, 4.1% in the second quintile, 10.3% in the third quintile, 48.5% in the fourth quintile, and 90.6% in the fifth quintile.

Table 1. Descriptive statistics of anthropometric measurements, components of body composition and handgrip strength in girls

	Mean	SD	Min	Max
Age	12.47	1.13	11.00	14.00
TV (cm)	156.26	8.16	116.30	177.00
TT (kg)	51.30	11.36	27.90	98.10
BMI (kg/m2)	20.80	3.78	13.40	34.30
BMI z	0.00	1.00	-1.85	3.45
BFP (%)	24.99	7.37	6.20	45.90
BFM (kg)	13.44	6.58	1.99	38.19
SMM (%)	33.18	2.40	23.60	39.70
SMM (kg)	16.88	3.18	9.18	28.35
FFM (kg)	37.85	5.97	24.18	68.15
MFR (kg/kg)	1.51	0.68	0.60	5.81
HGS (kg)	22.53	5.25	8.20	40.15
RHGS (kg/kg/m2)	1.10	0.25	0.36	1.92

TV = weight; TT= height; BMI = body mass index; BMI z= Z-Score of body mass index; BFP%= body fat percentage; BFM= body fat mass; SMM% = percentage of skeletal muscle mass; SMM = skeletal muscle mass; FFM = fat-free mass; MFR= ratio of skeletal muscle mass and fat component; HGS = handgrip strength; RHGS = relative handgrip strength (grip-to BMI ratio).

Table 2. Skeletal muscle mass ratio and fat component (MFR) shown through the quintiles of the body mass index (BMI) z values in girls

BMI	BMIz		MFR		Sarcopenia I degree		Sarcopenia II degree	
	Mean	SD	Mean	SD	f	%	f	%
Q1	-1.15	0.25	2.34	0.86	0	0.0%	0	0.0%
Q2	-0.65	0.12	1.71	0.40	4	4.1%	0	0.0%
Q3	-0.17	0.12	1.40	0.27	12	10.3%	0	0.0%
Q4	0.41	0.19	1.16	0.19	49	48.5%	6	5.9%
Q5	1.58	0.64	0.90	0.19	96	90.6%	53	50.0%
Total			1.51	0.68	161	30.3%	59	11.1%

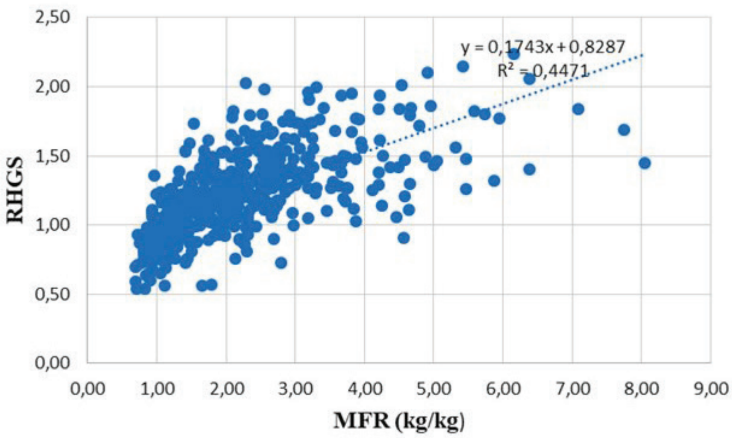
The class I MFR cut-off for girls (mean - 1SD of MFR for the 3rd BMI quintile) to determine sarcopenia = 1.130. The class II MFR cut-off for girls (mean - 2SDs of MFR for the 3rd BMI quintile) to determine sarcopenia = 0.860

Table 3 and graph 1 demonstrate Pearson's correlation coefficients between the relative values from the relative handgrip dynamometry test (kg/kg/m^2) and the MFR. Upon reviewing the table and graph, it is evident that there is a significantly positive correlation between the relative handgrip dynamometry test results (kg/kg/m^2) and the MFR in girls (r=0.349, p<0.001). Intercorelation between ratio of skeletal muscle mass and fat component, as well as relative handgrip strength, was analyzed in female candidates and presented in Table 3.

Table 3. Pearson's correlation between MFR and grip-to-BMI

	MFR (kg/kg)
RHGS (kg/kg/m2)	.349*

*Correlation is significant at the level of p < 0.001 (2-tailed).



GRAPH 1. Scatter plot between ratio of skeletal muscle mass and fat component, relative handgrip strength in female candidates

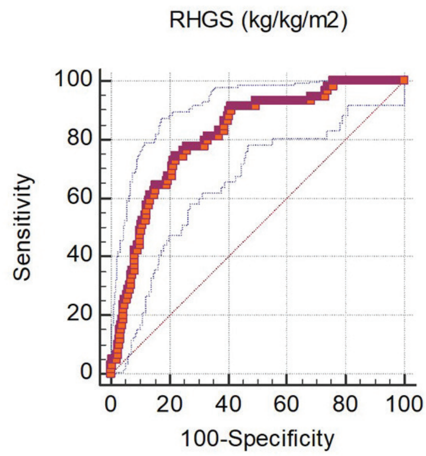
Table 4. Determination of the optimal cut-off value of relative handgrip strength in predicting sarcopenic obesity grade II in female candidates

Area under the ROC curve (AUC)	0.816
Standard Error [a]	0.027
95% Confidence interval [b]	0.781 to 0.848
z statistic	11.566
Significance level P (Area=0.5)	<0.001
Youden index J	0.526
Cut-off point	≤0.950
Sensitivity	74.58
Specificity	78.01
Sample size	532
Positive group [a]	59 (11. 09%)
Negative group [b]	473 (88. 91%)

*p<0.001.

The research found that determining the best cut-off for relative handgrip strength to predict grade II sarcopenic obesity in female candidates resulted in an area under the ROC curve with a value of 0.816 (95% CI 0.781–0.848), with a sensitivity of 74.58% and a specificity of 78.01%.

A logistic regression analysis was used to assess the relationship between relative hand grip strength and the risk of sarcopenic obesity grade II in female candidates. This analysis aimed to distinguish between candidates at risk and those not at risk. The results are shown in table 5. Upon reviewing the table, it is evident that the adjusted probability quotient for age (OR 95% CI) is 19.09 (9.43-38.66, p<0.001). In female candidates, it indicates that those who exceed the cutoff value (meeting the criterion reference standard) are 19 times less likely to have grade II sarcopenic obesity, based on the average MFR - 2SD (two standard deviations below the mean) for the 3rd quintile of BMI.



GRAPH 2. Receiver-operating characteristic curve on the relative handgrip strength (grip-to-BMI ratio) in girls (p<0.001)

Table 5. Relative handgrip strength in discriminating female respondents who are at risk. compared to those who are not at risk of grade II sarcopenic obesity

Explanatory variables	Unstandardized coefficient (B)	Wald statistics	p	OR (95% CI)
Years	.713	42.29	0.000	2.04 (1.64-2.53)
Sarcopenia class II				
MFR = >0.860	2.95	67.14	0.000	19.09 (9.43-38.66)
MFR = ≤0.860 (Ref)				1.000

*Dependent variable: The relative strength of the handgrip (Cut-off point ≤0.950kg/kg/m2)

Discussion

The findings of this research demonstrated that by using relative values from the handgrip dynamometry test (ratio of SMM and BFM), it is possible to identify female underage individuals who are at risk of sarcopenic obesity.

In this study, the prevalence of sarcopenic obesity II among girls was 11.1%, which was higher than the 3.8% found in the study by Kim et al (2016) on Korean girls. Nevertheless, in this study, when the authors defined sarcopenia class I as 1 standard deviation below the mean MFR for the 3rd BMI quintile, the prevalence was 24.3% in girls, as compared to 30.3% in the previous study (Kim et al., 2016). McCarthy and colleagues (2014) found that 9.8% of girls were at risk for class II sarcopenic obesity. According to Steffl et al's research in 2017, the prevalence of sarcopenic obesity risk class II was 9.3% for girls and 7.2% for boys. Other studies suggest that the cutoff point for relative handgrip strength (grip-to-BMI ratio) in girls aged 4 to 9 is estimated to be .680 kg/kg/m^2, while for boys it is .721 kg/kg/m^2. In a study conducted by Gontarev, Jakimovski, and Georgiev (2019), the prevalence of risk of sarcopenic obesity class II in younger school-aged boys and girls was found to be 5.9% and 9.2%, respectively. The researchers also found that the cutoff values for relative grip strength (specifically, the ratio of grip to BMI) in this group of subjects were 0.658 kg/kg/m^2 and 0.669 kg/kg/m^2 for boys and girls, respectively.

The findings of the study show that relative handgrip strength is highly effective (AUC=0.82) in determining the presence of sarcopenic obesity grade II in female participants. The criterion reference standard for evaluating grade II sarcopenic obesity in female candidates aged 11 to 14 years old is set at .950 kg/kg/m^2. This indicates that if girls score at or below this result on the handgrip dynamometry test divided by the body mass index, they are highly likely to have grade II sarcopenic obesity. Steffl et al found that the AUC in girls aged 10-14 years was 0.79 (95% CI 0.688–0.890, p<0.001). In females aged 11 to 14 years, the cut-off point (the criterion reference standard) for identifying grade II sarcopenic obesity is .920 kg/kg/m^2 (Steffl et al., 2017).

While sarcopenia has typically been linked to muscle mass loss in older adults, recent studies have found that sedentary children and adolescents can also develop sarcopenia (Kim et al., 2009). Unlike elderly candidates who develop sarcopenia due to degenerative processes, children and adolescents are at risk of developing sarcopenia for entirely different reasons. Obesity is likely a significant factor in the development of sarcopenia in children and adolescents due to the widespread prevalence of obesity at an epidemiological level globally (Coles, 2016; Lobstein, Baur & Uauy, 2004; Peulić et al., 2024).

This is primarily caused by insufficient physical activity and poor nutrition. Female adolescents may experience an increased risk of higher body fat percentage and lower muscle mass percentage due to physiological changes in body composition, decreased insulin sensitivity, hormonal changes, and psychological adjustments (Todd et al., 2015).

In children and adolescents, low muscle mass is often indicated by the MFR, which measures skeletal muscle mass and fat content (Kim, Hong, & Kim, 2009). Unfortunately, the calculation of MFR relies on anthropometric measurements and body composition assessments that necessitate the utilization of specialized equipment like DXA, BIA, computed tomography, or magnetic resonance imaging. Alternatively, measuring grip strength is a cost-effective and easily applicable method. When the handgrip dynamometry test results are adjusted for relative values by dividing the absolute values by the body mass index (grip-to-BMI ratio), it is possible to differentiate between children and adolescents who are at risk of sarcopenic obesity and those who are not at risk. Children with lower relative handgrip strength are at a higher risk of being diagnosed with sarcopenic obesity, as determined by the MFR which looks at skeletal muscle mass and fat component. The standard interpretation of the AUC grip-to-BMI indicates that it accurately estimates sarcopenia.

One of the main limitations is that the sample used in the study did not capture the diversity of under-aged female candidates from the Republic of North Macedonia as it did not include candidates from all eight planning regions. Nevertheless, the sample size was adequate and accurately represented. Determining precise cutoff values is challenging because increasing sensitivity will inevitably lead to a reduction in specificity.

Conclusion

The set criteria refer to standard limits that take into account the relative handgrip strength, providing a simple and cost-effective way to identify young females who may be at risk of second-degree sarcopenic obesity, making it a useful field method. While the methods presented in this study may not definitively diagnose sarcopenic obesity in younger individuals, they can still be a cost-effective and useful way to detect those who might be at risk and in need of further medical evaluation, dietary changes, or physical exercise programs.

The findings from this study enable countries with comparable economic, ethnic, and social backgrounds to utilize these boundary values. Physical education teachers and public health professionals can also utilize the findings from the research. Incorporating a healthy diet and regular physical activity should be a key aspect of overall health policy and daily routines, targeting not just individuals but also families and the entire population.

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Conflict of Interest
The authors state that there is no conflict of interest.

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