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Standing-Long-Jump Test Application in Identifying Female Adolescents at Risk of Sarcopenic Obesity

Aplicación de la Prueba de Salto de Longitud de Pie para Identificar a Adolescentes con Riesgo de Obesidad Sarcopénica

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SUMMARY: The identification of children and adolescents who are at risk of sarcopenic obesity development often requires specialized equipment and expensive test procedures. Therefore, the establishment of cheaper and faster methods would be greatly useful, especially if they could be applied in the field. The study's objective was to establish if identification of female adolescents who suffer the risk of developing sarcopenic obesity can be obtained through the standing-long-jump test application. To achieve the research objectives, various anthropometric and body composition measurements were performed and lower limb explosive strength was assessed using the standing long jump fitness test. The research was conducted on a sample of 535 female respondents randomly selected from 9 elementary schools in the Skopje region of the Republic of North Macedonia. The respondents were divided into quintiles according to BMI z-scores, and the arithmetic means and SD about muscle-to-fat ratio were calculated for each quintile. The cutoff was determined based on the mean and standard deviation of the muscle-to-fat ratio for the 3rd quintile of BMI and the percentage of respondents with sarcopenic obesity was examined. The optimal cut-off value of the long jump fitness test results for predicting sarcopenic obesity in an adolescent girl showed that the area under the ROC curve was 0.781 (95 % CI 0.743–0.815). The standing-long-jump test values, on grounds of odds ratio (OR 95 % CI) about the girls at risk of sarcopenic obesity development, which was identified on muscle-to-fat ratio base, were 8.76 (4.39 - 17.54, p 0.001). It can be used to predict sarcopenic obesity presence in female adolescents, which can be vital in case of health intervention.

KEY WORDS: Muscle-to-fat ratio; Bioelectrical impedance; Skeletal muscle mass; Obesity.

INTRODUCTION

Obesity among school youth is an increasing and major health problem worldwide. According to the research of NCD Risk Factor Collaboration (2017), between 1975 y. and 2016 y. obesity among school children in the world increased from 0.9 % to 7.8 % for boys and from 0.7 % to 5.6 % for girls. Overweight/obesity among Macedonian adolescents is approximately 24 % (Myrtaj *et al*., 2018). The recent COVID-19 pandemic is expected to result into a further increase of that tendency (Jia *et al*., 2021). Low values of muscle mass or an imbalance between muscle mass and fat tissue are described as sarcopenic obesity in elderly persons (Park & Yoon, 2013). Namely, sarcopenia is accompanied by weight loss due to the loss of muscle mass and decrease in muscle strength and function.

The 'sarcopenia' term (from Greek "sarx" or flesh + "penia" or loss) was first introduced in 1989 y. by Irwin Rosenberg as a term describing the muscle mass loss in the elderly population (Rosenberg, 1989). Before the European Working Group on Sarcopenia in Older People had published its definition and diagnostic criteria in 2010, the sarcopenia diagnosing was not standardized, and different methods were used by researches and health professionals. The lack of a universally accepted definition and criteria resulted in inconsistencies in diagnosis and used to hamper the comparisons between studies. In 2010 the European Working Group on Sarcopenia in Older People (EWGSOP) proposed a sarcopenia definition, which included assessment of muscle function as well.

The EWGSOP recommended using the presence of both low muscle mass and low muscle function (strength or performance) in sarcopenia diagnosing (Cruz-Jentoft *et al*., 2010). Yet, according to the 2019 EWGSOP 2 revised

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consensus, the muscle strength has become the primary parameter in sarcopenia diagnosing. Sarcopenia occurrence is likely when low muscle strength is observed (Cruz-Jentoft *et al*., 2019).

It is not known whether the lack of muscle mass in female adolescents has a contribution to obesity or on the contrary, but previous research studies indicate that obesity seems to contribute to the sarcopenia development, resulting in what is called "sarcopenic obesity" (Zembura & Matusik, 2022). In girls the adolescent period is associated with changes in eating and activity habits. Less reliance on parental provision and choice of food, along with the reduced participation in physical activity and sports, can create an energy imbalance, which can lead to gaining weight. The physiological changes in body composition, insulin sensitivity decrease, hormonal changes and psychological adjustments may further increase the risk of excess body fat percentage and reduction of muscle mass percentage in female adolescents (Todd *et al*., 2015).

A female adolescent may not look obese, but, at the same time, they may have a relatively low percentage of muscle mass compared to their peers, which may be due to a high percentage of body fat and may result in the adolescent looking and functioning seemingly normally. This makes it difficult to identify female adolescents who may be suffering from sarcopenic obesity.

Therefore, the existence of a diagnostic tool to identify female adolescents who have sarcopenic obesity is especially significant, because neglecting the treatment of any disease in adolescent can result in health problems later in life.

McCarthy *et al*. (2014) point that the ratio of muscle mass and fat component can be used as an indicator of metabolic risk in children and adolescents. Also, Park & Yoon (2013), indicate that the relative ratio of skeletal muscle mass to body composition, rather than absolute mass, can be used as a strong predictor and play a key role in the development of metabolic syndrome. McCarthy *et al*. (2014), proposed a method for calculating the critical reference point in children and adolescents using the muscle-to-fat ratio (MFR) and body mass index. Also, Kim *et al*. (2016), in their research, applied the method of McCarthy *et al*. (2014), to identify children and adolescents who have sarcopenic obesity. Unfortunately, the calculation of MFR relies on precise body composition measurements that require appropriate equipment and professional staff, which presents a problem when a large group of people needs to be measured. However, it may be used to diagnose sarcopenic obesity in practice measurement of muscle strength rather than skeletal muscle mass.

We believe that the muscle strength evaluation through tests for muscle fitness assessment in order to identify sarcopenic obesity in female adolescents can have an advantage in terms of feasibility and efficiency, since the tests are easy to apply as well as indicative of the amount of muscles and muscle function.

Despite the growing interest in the study of sarcopenic obesity, the concept has not yet been operationalized in terms of identification criteria (Orsso *et al*., 2019). The research development in this area will help practitioners to get a better recognition of sarcopenic obesity not only in pediatric patients of chronic diseases, but very probably in the pediatric population of healthy look as well.

Considering the above, the main objective of the present research is to establish if the application of standing-long-jump test can identify female adolescents who suffer the risk of developing sarcopenic obesity.

MATERIAL AND METHOD

Participants. The research was carried out on a sample of 535 female respondents randomly selected from 9 elementary schools in the Skopje region of the Republic of North Macedonia. The average age of the participants was 12.47 (± 1.1) years.The study included all students whose parents gave consent for their children to participate in the research and who were psychophysically healthy and regularly attended Physical and Health Education classes. The respondents were treated in accordance with the Helsinki Declaration 1961 (2013 revision, Brazil). The protocols were approved by the Ethics Committee Number (549, 10.05.2021) at the University of "Ss. Cyril and Methodius" in Skopje.

Outcome Measures. The anthropometric measurements were carried out according to the methodology of the International Biological Program (IBP). The weight was measured in standard conditions, using the Tanita BC-418MA model of digital scale with a measurement precision of 0.1 kg. The measurement was carried out in the morning before breakfast and the participants wore light clothing. The students' height was measured in a standard position without shoes using a stadiometer with an accuracy of 0.1 cm. Based on the height and weight of each respondents, the body mass index – BMI (kg/m2) was calculated.

Body composition components were determined using the bioelectrical impedance method. The measurement was carried out using a Body Composition Monitor model "Tanita BC-418MA", single frequency (50 Hz). Before starting the measurement, the parameters sex, age and body height of the respondents were entered in the Body Composition Monitor. 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). In order have as accurate and precise results as possible, the results obtained from the measurement, namely body composition assessment, and all prerequisites were met before each measurement (Heyward, 2006).

The standing-long-jump test was used to assess the strength of the lower limbs. To perform the test, one needs a measuring tape with an accuracy of 1 cm, a flat non-slip surface with a marked jump ?r?? on which the place of the bounce is at the same level as the place of landing. It is obligatory for the legs to be brought together for jumping and landing. The student needs to be in a proper Physical and Health Education class's equipment when jumps. The task of the student is to jump as far as possible. The point of contact of the heel with the surface, which is closest to the bounce line, is taken as an accurate measure. Two jumps are performed, the incorrectly performed jump is repeated. The longer jump is recorded. The result is presented in centimeters.

The measurement was carried out under normal school conditions as part of regular physical education lessons. The measurement was carried out by experts in the field of kinesiology who were previously trained in fitness test measurements.

Sarcopenia Risk Diagnostics. In order to diagnose the female adolescent sarcopenic obesity the methodology according to McCarthy *et al*. (2014) and Kim *et al*. (2016) was used. Participants were divided into quintiles according to BMI z -values and arithmetic means, and standard deviations were calculated for the derived variable from the ratio of skeletal muscle mass to the fat component (MFR) for each quintile. A cut-off point was defined using mean and standard deviation of muscle-to-fat ratio for the 3rd body mass index quintile (ie, cut-off point = mean value – 2SD of muscle-to-fat ratio for the 3rd body mass index quintile), and the proportions of sarcopenic obesity subjects were examined.

Statistics and Data Analysis. First, the normality of the data was checked using the Kolmogorov-Smirnov test. Data was presented as the mean and standard deviation (SD). The relationship between the applied variables was determined by applying the Pearson correlation coefficient (r). The limit values (criterion reference standards) of the standing-long-jump test, with the help of which we will successfully distinguish female adolescents who may be at risk of sarcopenic obesity, was determined through analyzing the Receiver Operating Characteristic Curve. Based on the Youden index, cutoff values, specificity, sensitivity, and positive and negative predictive values were determined.The diagnostic accuracy of the test was determined based on the AUC: AUC < .500 - the test is not useful; for .500 < AUC < .600 - the test is poor; in the case of .600 < AUC < .700 - the test is discriminatory enough; if .700 < AUC < .800 - the test is good; for .800 < AUC < .900 - the test has a very good discriminative power; for .900 < AUC < 1,000 - the diagnostic accuracy of the test is excellent.

By multinomial logistic regression with age controlling, the probability (eng. odds ratio - OR) of developing sarcopenic obesity according to the MFR was determined when the participants was classified as having a sarcopenic obesity risk according to the limit values of thestanding-jump-test. Data were processed with the statistical packages of SPSS for Windows Version 26.0 (SPSS Inc., Chicago, IL, USA) and MedCalc Version 19.1.3.

RESULTS

Table I represents the arithmetic means, standard deviations, minimal and maximal results of each variable individually in the tested population. Table II presents the ratio of skeletal muscle mass and fat component (MFR) through the quantiles of z-values of body mass index (BMI) in the girls. It can be seen that the limit value for sarcopenic obesity (arithmetic mean of MFR - 2 SD for the 3rd BMI quantile) in the girls is 0.860, and the proportion below this limit value was 11.1 %. In the first quantile, the percentage of girls with sarcopenic obesity compared to those without it was 0.0 %, for the second quantile 0.0 %, for the third quantile 0.0 %, for the fourth quantile 5.9 %, and for the fifth quantile 50.0 %.

Table I. Characteristics of study subjects

	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/m^2)	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
LEN (kg)	37.85	5.97	24.18	68.15
MFR (kg/kg)	1.51	0.68	0.60	5.81
SLJ (sm)	139.15	23.26	88.20	209.00

Table II. Skeletal muscle-to-fat ratio (MFR) shown through the quantiles of z-values of body mass index (BMI) in girls.

BMI	BMIz		MFR		Sarcopenic obesity	
	Mean	SD	Mean	SD	f	%
Q1	-1.15	0.25	2.34	0.86	0	0.0
Q2	-0.65	0.12	1.71	0.40	0	0.0
Q3	-0.17	0.12	1.40	0.27	0	0.0
Q4	0.41	0.19	1.16	0.19	6	5.9
Q5	1.58	0.64	0.90	0.19	53	50.0
Total			1.51	0.68	59	11.1

MFR cut-off for girls (mean - 2SDs of MFR for the 3rd BMI quintile) to determine sarcopenic obesity = 0.860

By Figure 1**,** it can be seen that the participants' standing long jump test has a low positive and statistically significant correlation with muscle mass to fat ratio (r = 0.285, p < 0.001).

The optimal cut-off point of the long-jump fitness test's results when predicting the sarcopenic obesity in female participants showed that the size of the area under the ROC curve has a value of 0.781 (95 % CI 0.743 – 0.815), with a specificity of 62.13 % and a sensitivity of 83.05 %. This suggests the conclusion that the standing-long-jump test has a good discriminative power in predicting sarcopenic obesity class II among the participants (Table III, Fig. 2). Cut-off point (the criterion reference standard) for assessment of sarcopenic obesity in female participants aged from 11 to 14 is 133 cm. This means that the respondents who perform equally or worse on the standing-long-jump performance test have a significantly higher risk of suffering from sarcopenic obesity.

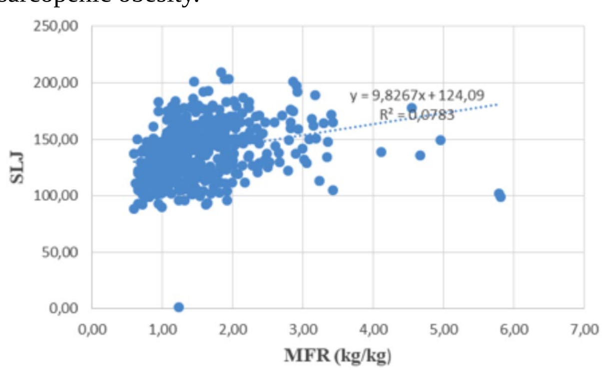

Fig. 1. Scatter plot between the muscle-to-fat ratio and the standing long jump fitness test in female adolescents.

In order to determine the relationship between the values of the standing-long-jump test in differentiating the female respondents who are at risk from those who are not at risk of sarcopenic obesity, a multinominal logistic regression analysis was applied. The review of Table IV shows that the odds ratio, after adjusting for the age (OR 95 % CI), is 8.76 (4.39 - 17.54, p < 0.001) in the female respondents. It shows that participants who score better results than the cut-off point (meet the criterion reference standard) are 9 times less likely to have sarcopenic obesity based on the arithmetic mean of MFR - 2 SD (minus two standard deviations) for the 3rd BMI quantile.

Table III. Cut-off value of standing long jump fitness test results in the prediction of sarcopenic obesity among female adolescents.

Area under the ROC curve (AUC)	0.781
Standard Error [a]	0.0255
95 % Confidence interval [b]	0.743 to 0.815
z statistic	10,997
Significance level P (Area=0.5)	<0.0001
Youden index J	0.4518
Cut-off point	≤133
Sensitivity	83.05
Specificity	62,13
Sample size	529
Positive group [a]	59 (11.15 %)
Negative group [b]	470 (88.85 %)

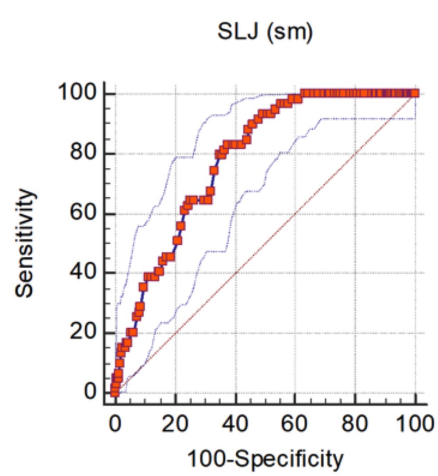

Fig. 2. Receiver-operating characteristic curve of the standing-long-jump test in the girls (p < 0.001).

Table IV. Standing-long-jump test values in differentiating exposed-to-risk female participants from those not at risk of sarcopenic obesity.

Explanatory variables	Unstandardized coefficient (B)	Wald statistics	p	OR (95 % CI)
Years	.251	8.96	0.000	1.25 (1.09-1.51)
Sarcopenic obesity				
MFR = >0.860	2.17	37,58	0.000	8.76 (4.38-17.54)
MFR = ≤0.860 (Ref)				1.000

*Dependent variable: Standing-long-jump test (Cut-off point ≤133 cm)

DISCUSSION

Previous research studies indicate that sarcopenic obesity can be diagnosed through body composition analysis (Cauley, 2015). However, the direct assessment of body composition requires expensive equipment and trained specialists, and the ability of having cheap and quick evaluation of the body composition specific aspects in children (eg, low SMM) would prove to be a valuable/useful method. The study results suggest that the standing-long-jump fitness test can be used in identifying female adolescents who are under the risk of sarcopenic obesity.
Although sarcopenia has traditionally been associated with loss of muscle mass in elderly persons, recent studies indicate that sedentary children and adolescents can also develop sarcopenia (Kim *et al*., 2016). Unlike older people, in whom sarcopenia is more common due to degenerative processes, the cause of the risk of developing sarcopenic obesity in children and adolescents is completely different. Most likely, obesity - caused by poor diet, sedentary lifestyle and lack of physical activity - plays an important role in the development of sarcopenia in children and adolescents, as the prevalence of obesity in children and adolescents worldwide has reached an epidemiological level (Coles *et al*., 2016).

As the body fat percentage increases, the ratio of skeletal muscle mass to fat component (MFR) decreases in favor of body fat and, probably, the muscle strength decreases. Therefore, measuring the muscle strength may be a logical alternative to the expensive body composition measurements in identifying female adolescents at risk of sarcopenic obesity. As the fat-component percentage increases, so the muscle-to-fat ratio decreases in favor of the fat component, which, most likely, leads to a decrease in the quality of muscle strength. Therefore, the muscle strength evaluation may be an alternative method to the expensive measurements (BMI, DEXA, computed tomography or magnetic resonance image) of body composition in identifying female adolescents at risk of sarcopenic obesity. Although there is an association between muscle strength and sarcopenic obesity in children and adolescents, reduced muscle strength is associated with sarcopenia in older adults. In particular, a poor score on the handgrip dynamometer test, a method of assessing grip strength, is a better indicator for diagnosing sarcopenia in older adults than a lower percentage of skeletal muscle mass (Legrand *et al*., 2013). Along with that, the absolute hand-grip strength (Cruz-Jentoft *et al*., 2010) and relative hand-grip strength (grip-to-BMI ratio) (McLean *et al*., 2014) are used for the clinical assessment of sarcopenia in elderly persons. However, regarding children and adolescents, although there is a high correlation between body weight, height and hand-grip strength (Ploegmakers *et al*., 2013), there is a lack of information on the relationship between fat mass and muscle mass on the one hand and the explosive power of the lower limbs on the other.

The main indicator of low skeletal muscle mass in children is the fat-to-muscle ratio (Kim *et al*., 2016). Unfortunately, calculating MFR requires specialized and expensive equipment such as CT, MR, DXA or BIA. On the other hand, measuring strength through the standing-long-jump fitness test is a relatively simple and less expensive method. Female adolescents who achieve lower results in the standing-long-jump fitness test are much more likely to be diagnosed with sarcopenic obesity than measurements based on MFR (skeletal muscle mass to fat component ratio). According to the standard interpretation of the AUC, the standing-long-jump fitness test provides a relatively accurate estimation of sarcopenic obesity in adolescent females.

In the present study, the prevalence of sarcopenic obesity in girls was 11.1 %, compared with the results of Kim *et al*. (2016), which found that 3.8 % of Korean girls were at risk of developing sarcopenic obesity. However, when sarcopenic obesity class I was calculated as 1 SD lower than the mean muscle-to-fat ratio for the 3rd BMI quintile, the prevalence was 24.3 %, in girls, while in this study class I, sarcopenia was found in 30.3 % of girls (Kim *et al*., 2016). In the McCarthy *et al*. (2014) research study, the prevalence of sarcopenic obesity risk was 9.8 % among girls. In the research of Steffl *et al*. (2017), the prevalence of sarcopenic obesity risk was 9.3 % among girls and 7.2 % among boys. In addition, the authors established that the cut-off value of grip-to-BMI ratio for girls aged 4 to 9 is 0.680 kg/kg, and for boys 0.721 kg/kg. In the research of Gontarev *et al*. (2020), the prevalence of sarcopenic obesity risk among children aged 6 to 10 was 5.9 % among girls and 9.2 % among boys. Also, the authors determined that the limit value for the relative hand-grip strength (cut - off point of grip - to - BMI ratio) for girls at the age of 6 to 10 years are 0.658 kg / kg, and for boys 0.669 kg / kg. Although the bioelectrical impedance method has been shown to be valid and reliable in determining body composition components (Janssen *et al*., 2000), such systems do not allow the direct measurement and easy assessment of body composition components through the transmission of an electrical signal the body, which is calculated using a set of normative anthropometric data. Therefore, direct measurement of body composition such as DXA, MRI and CT is possible, which can provide more accurate results. In addition, although MFR can be calculated using bioelectrical impedance (BIA), which provides information about the amount of body fat and muscle components, it cannot determine the underlying cause of MFR (i.e., changes in muscle-to-muscle ratio). may be due to chronic inflammation,myopathy, malnutrition, physical inactivity, etc. Therefore, muscle-to-fat ratio should not be used for the clinical diagnosis of sarcopenic obesity in femele adolescent, but to provide rapid, valid and reliable information on a "first look" at adolescent's body composition, identifying adolescents who need a more detailed medical examination with more sophisticated diagnostic equipment (Steffl *et al*., 2017).

Exercises aiming to improve muscle strength are recommended by a number of health organizations due to their impact in improving muscle strength, power, hypertrophy, muscle endurance, speed, coordination as well as preventing a number of diseases (Kell *et al*., 2001; Stump *et al*., 2006). The results of longitudinal studies indicate that changes in muscle strength from childhood to adolescence are negatively related to changes in total adiposity, while the association between muscle strength and changes in central adiposity is less pronounced (Ruiz *et al*., 2009).

This study contains some limitations that must be mentioned. Firstly, the sample does not represent the entire population of female adolescents from the Republic of North Macedonia, since participants from all eight planning regions were not included in it. However, the sample was sufficiently large and representative. Secondly, the exact determination of cut-off point is very difficult, since any increase in sensitivity will be accompanied by a decrease in specificity.

CONCLUSIONS

The present study is one of the first studies to operationalize the identification of sarcopenic obesity through the muscle fitness in apparently healthy pediatric population. The strength assessed by standing-long-jump fitness test is a valid marker in identifying sarcopenic obesity in female adolescents. Future research studies should aim to confirm these findings, using samples from other populations. The results of this research allow countries with similar social, economic characteristics and ethnic to use these border values. The research results can also be used by physical education teachers and public health professionals.

SYLEJMANI, B.; MALIQI, A.; VESELI, R.; GONTAREV, S. & GEORGIEV, G. Aplicación de la prueba de salto de longitud de pie para identificar a adolescentes con riesgo de obesidad sarcopénica. *Int. J. Morphol., 42(2)*:294-300, 2024.

RESUMEN: La identificación de niños y adolescentes que corren riesgo de desarrollar obesidad sarcopénica a menudo requiere equipos especializados y procedimientos de pruebas costosos. Por lo tanto, el establecimiento de métodos más baratos y rápidos sería de gran utilidad, especialmente si pudieran aplicarse en el campo. El objetivo del estudio fue establecer si la identificación de mujeres adolescentes que sufren riesgo de desarrollar obesidad sarcopénica se puede obtener mediante la aplicación de la prueba de salto de longitud de pie. Para lograr los objetivos de la investigación, se realizaron diversas mediciones antropométricas y de composición corporal y se evaluó la fuerza explosiva de los miembros inferiores mediante la prueba de aptitud de salto de longitud de pie. La investigación se realizó con una muestra de 535 mujeres encuestadas seleccionadas al azar de 9 escuelas primarias de la región de Skopje, en la República de Macedonia del Norte. Los encuestados se dividieron en quintiles según las puntuaciones z del IMC, y se calcularon las medias aritméticas y la DE sobre la relación músculo-grasa para cada quintil. El límite se determinó en función de la media y la desviación estándar de la relación músculo-grasa para el tercer quintil del IMC y se examinó el porcentaje de encuestados con obesidad sarcopénica. El valor de corte óptimo de los resultados de la prueba de condición física de salto de longitud para predecir la obesidad sarcopénica en una adolescente mostró que el área bajo la curva ROC fue 0,781 (IC del 95 %: 0,743–0,815). Los valores de la prueba de salto de longitud de pie, sobre la base del odds ratio (OR IC del 95 %) sobre las niñas en riesgo de desarrollar obesidad sarcopénica, que se identificó sobre la base del ratio músculo-grasa, fueron 8,76 (4,39 - 17,54, p. 0,001). Puede utilizarse para predecir la presencia de obesidad sarcopénica en adolescentes, lo que puede ser vital en caso de intervención sanitaria.

PALABRAS CLAVE: Relación músculo-grasa; Impedancia bioeléctrica; Masa de músculo esquelético; Obesidad.

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