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ORIGINAL ARTICLE

Assessing Sarcopenic Obesity Risk in Children During the COVID-19 Pandemic: Grip-to-BMI Ratio

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ÖZET

Amaç: Bu çalışma, COVID-19 pandemisi sırasında 6-10 yaş arasındaki Türk çocuklarında sarkopenik obezite sıklığını incelemeyi ve tanısal yöntemleri karşılaştırmayı amaçlamaktadır. **Yöntem:** : Bu çalışmaya toplam 431 sağlıklı çocuk (230 kız, 201 erkek) dahil edildi. Boy, kilo ve beden kitle indeksi (BKİ) gibi çeşitli antropometrik ölçümler alındı. Ayrıca, vücut bileşimi, yağ kütlesi, iskelet kas kütlesi ve kas-yağ oranını (KYO) belirlemek için biyoelektrik empedans analizi (BİA) kullanılarak değerlendirildi. Ek olarak, kavrama gücü ölçüldü ve kavrama gücü/BKİ oranı belirlendi. Sarkopenik obeziteyi tanımlamak için McCarthy'nin yöntemi kullanılarak KYO eşik değerleri belirlendi. ROC eğrileri ile, kavrama gücü/BKİ oranının sarkopenik obezite riskini belirlemek için uygulandı. **Bulgular:** Kız çocuklarında sarkopenik obezite sıklığı %8,7, erkek çocuklarda %10,4 olarak bulundu. Kas/yağ oranı (KYO) ile karşılaştırıldığında, kavrama gücü/BKİ indeksi oranının sarkopenik obezite riskini saptamada önemli duyarlılık gösterdiği görüldü. 6-8 yaş grubundaki erkek ve kız çocuklarında kavrama gücü/BKİ oranı ile KYO arasındaki korelasyon zayıf (erkeklerde r=0,363, kızlarda r=0,458, p<0,001) iken, 9-10 yaş grubundaki erkek ve kız çocuklarında bu ilişki güçlü bulundu (Erkeklerde r=0,628, p<0,001; kızlarda r=0,612, p<0,001). 6-8 yaş grubu kız çocuklarında KYO'nın 3. kuintilde BKİ ile belirlenen kesme değeri ≤0,81, 9-10 yaş grubu kız çocuklarında ise ≤0,78 olarak saptandı. 6-8 yaş grubu erkek çocuklarında kesme değeri ≤0,96, 9-10 yaş grubu erkek çocuklarında ise ≤0,61 olarak bulundu. Kavrama gücü/BKİ oranı, sarkopenik obezite riskini tanımlamak için optimal kesme değerleri belirlemede başarıyla kullanıldı. Yaşa göre düzeltilmiş ikili regresyon modelinde, kız çocukları için OR (%95 GA): 11,833 (3,353-41,757) p<0,001; erkek çocuklar için OR (%95 GA): 11,705 (3,318-41,290) p<0,001 olarak hesaplandı. **Sonuç:** Bu araştırma, COVID-19 pandemisinin çocuk sağlığı üzerindeki etkilerini aydınlatmaktadır. Özellikle sokağa çıkma yasakları ve okul kapanmaları nedeniyle egzersiz fırsatlarının azalması ve bu dönemde beslenme alışkanlıklarındaki değişiklikler, çocukların vücut kompozisyonunu olumsuz etkilemiş olabilir. Çocuklarda vücut kompozisyonu göstergelerini tahmin etmek için BIA kullanılması bu çalışmada değerli bilgiler sunmaktadır. Çalışma, sarkopenik obezite riskini belirlemek için kavrama gücü/BKİ oranının dikkate alınması gerektiğini önermektedir ve kavrama gücü/BKİ çocuk vakalarda bir tarama ölçüsü olarak kullanılabilir.

Anahtar kelimeler: Biyoelektrik impedans analizi, COVID-19 pandemisi, Çocuklar, Sarkopenik obezite, Vücut kompozisyonu

ABSTRACT

Aim: The present investigation aimed to examine the prevalence of sarcopenic obesity in Turkish children aged 6-10 years during the COVID-19 pandemic, while also conducting a comparison of diagnostic methods. **Methods:** A total of 431 healthy children (230 females, 201 males) were recruited for this study. Various anthropometric measurements, including height, weight, and body mass index (BMI), were collected. Furthermore, body composition was assessed through the utilization of bioelectrical impedance analysis (BIA) to ascertain fat mass, skeletal muscle mass, and the muscle-to-fat ratio (MFR). Additionally, grip strength was measured to determine the grip strength-to-BMI ratio. McCarthy's framework was employed to define sarcopenic obesity based on MFR cut-offs. Receiver operating characteristic curves were implemented to evaluate the efficacy of the grip strength-to-BMI ratio in identifying the risk of sarcopenic obesity. **Results:** The prevalence of sarcopenic obesity was found to be 8.7% in females and 10.4% in males. In comparison to the MFR, the grip strength-to-BMI ratio exhibited considerable sensitivity in detecting the risk of sarcopenic obesity. The correlation between the ratio of grip strength to BMI and the muscle-to-fat ratio (MFR) was found to be weak among boys and girls aged 6-8 years (r=0.363, r=0.458, p<0.001), while it was strong among boys and girls aged 9-10 years (boys: r=0.628, p<0.001; girls: r=0.612, p<0.001).

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For girls aged 6-8 years, the cut-off value for the MFR in the 3rd quintile, as determined by the BMI, was found to be ≤0.81, while for girls aged 9-10 years, it was ≤0.78. For boys aged 6-8 years, the cut-off value was ≤0.96, and for boys aged 9-10 years, it was ≤0.61. The grip strength-to-BMI ratio was successfully used to establish optimal cut-off points for defining the risk of sarcopenic obesity. In the age-adjusted binary regression model, the odds ratio (OR) for girls was: 11,833 %95 CI (3,353-41,757) p<0,001, while for boys, it was OR 11,705, CI (3,318-41,290) with p<0.001.

Conclusion: The research sheds light on the effects of the COVID-19 pandemic on child wellness. Specifically, reduced opportunities for exercise due to lockdowns and school closures, coupled with potential changes in nutrition during this period, could have negatively impacted body composition in children. By applying BIA to estimate body composition indicators amongst a sample of young participants, the study provides valuable insights. It suggests the grip-BMI ratio warrants consideration as a screening metric to identify at-risk pediatric demographics.

Keywords: Bioelectrical impedance analysis, COVID-19 pandemic, Children, Sarcopenic obesity, Body composition

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INTRODUCTION

Excess weight gain among youth has emerged as a significant worldwide health issue. Data from the World Health Organization (WHO) in 2016 indicates that around 340 million children and adolescents between the ages of 5-19 were classified as either overweight or obese. The statistics from the WHO highlight the scale of the challenge posed by pediatric obesity on a global scale (1). The alarming rise in obesity rates on a global level is further underscored by these statistics. Specifically, data shows that between 1975 and 2016, the prevalence of overweight increased considerably among both boys and girls - rising from 0.7% to 5.6% for boys and 0.9% to 7.8% for girls (1). Nationally, statistics from Turkey reveal that as of 2016 obesity levels were 8.5% among girls and 9.9% among boys according to COSI-TR-2016 data (2). These findings highlight the concerning trends in pediatric weight status both internationally and domestically within Turkey over recent decades (2).

However, given unique events such as the COVID-19 pandemic, there is concern that obesity rates may increase even more (3). The pandemic has caused notable shifts in the daily routines of children. These changes include reduced physical activity, increased screen time, and alterations in dietary habits, all of which are consequences of the COVID-19 pandemic (3,4). Research conducted during this period indicates an increase in weight among children and adolescents (5). Reduced physical activity during the pandemic is a cause for concern as it can lead to more cases of obesity and overweight. The lockdown has disrupted children's daily routines, leading to decreased physical activity and changes in eating habits. These factors may contribute to the increase in obesity. Therefore, it's essential to thoroughly investigate childhood obesity during the COVID-19 pandemic and comprehend the factors involved.

Sarcopenic obesity (SO) is now a recognized condition among adults, characterized by increased body fat and low muscle mass (6). This term combines obesity (excess body fat) and sarcopenia (insufficient muscle mass) and has gained popularity in recent years (7,8,9). Sarcopenia, typically associated with the elderly, has also been observed in children recently (10). In the pediatric population, SO is characterized by increased body fat and reduced muscle mass, often accompanied by limitations in physical fitness.

The situation becomes more complex due to the worldwide prevalence of obesity. It's unclear whether the lack of muscle mass in children leads to obesity or if obesity contributes to the development of sarcopenia, resulting in 'sarcopenic obesity (8). Studies indicate that sarcopenia in children and adolescents is linked to a range of health concerns, including insulin resistance and high-risk metabolic conditions such as Type 2 Diabetes Mellitus (DM), which can result in various health complications. (11).

As children go through growth and developmental factors such as adolescence, which can impact muscle mass and strength, it's crucial to employ standardized measures to account for these variables. The identification of sarcopenic obesity in children poses a challenge. Therefore, the development of a diagnostic tool for the detection of sarcopenic obesity in children would be highly valuable in addressing underlying conditions during childhood and potentially preventing future health issues.

Various methods are employed to estimate muscle mass, with computed tomography (CT) and magnetic resonance imaging (MRI) considered gold standards due to their high accuracy (12). However, there are limitations to routine clinical use of these imaging techniques, including high costs, limited access to equipment, radiation exposure, and contraindications for scanning (13).

Children mature and develop at varying rates. To account for this, McCarthy et al. (13) introduced the muscle-fat ratio (MFR), determined by the ratio of skeletal muscle mass (SMM) to body fat mass (BFM). McCarthy and colleagues also established MFR cut-off values, using a combination of body mass index (BMI) and MFR. Building upon this research, Kim et al. (14) proposed applying McCarthy's method to identify children at risk of sarcopenia.

In clinical practice, assessing muscle strength, particularly hand grip strength, is a common approach for diagnosing conditions such as sarcopenia. Cruz-Jentoft et al. (12) recommended hand grip strength as an indicator of sarcopenia due to its advantages for quick and field-based assessments. To accommodate variations in maturation and body size among children, grip strength is typically expressed relative to other measures. In this context, the grip-to-BMI ratio has been proposed as a relative hand grip strength measure for diagnosing sarcopenia in the elderly (15). However, there is limited available information concerning the

relationship between the grip-to-BMI ratio and the muscle-fat ratio (MFR) in children (13).

This study aims to investigate the development of sarcopenic obesity (SO) in children during the COVID-19 pandemic-induced closure period and compare two diagnostic methods for SO. By addressing this important aspect of children's health, this research seeks to enhance our understanding of the impact of the COVID-19 pandemic on health.

MATERIAL AND METHODS

Design

The study was conducted prospectively with children aged 6 to 10 years who visited the General Pediatrics Department of Gülhane Training and Research Hospital for routine check-ups between December 16, 2021, and March 16, 2022.

Population and Sample

A total of 432 participants were initially included. However, one participant was diagnosed with Celiac disease and was subsequently excluded from the study. Therefore, the study was completed with 431 participants.

Inclusion Criteria

During the study, a physical activity questionnaire (16) was employed to assess the mobility status of completely healthy children between the ages of 6 and 10. Informed consent forms were obtained from the families who agreed to participate in the study.

Exclusion criteria

Individuals with chronic illnesses, premature births, diagnosed and treated eating disorders, those unable to follow instructions, those who have entered puberty, those who presented after a full meal and in the afternoon, and those with symptoms such as diarrhea, vomiting, and fever that could lead to dehydration were not included in the study.

Data Collection

A survey consisting of a total of 78 questions was completed for the research. The first 24 questions of the form included participants' demographic information, while questions 24-50 covered details about the participants' families, such as their type, place of residence, school-related characteristics, nutrition, sleep, screen time, step counts, sitting durations, and more. Questions 51-78 in the survey pertained to anthropometric measurements conducted by the researchers. Patient measurements were taken in the morning, on an empty bladder. These measurements were conducted by the same trained individual, an experienced pediatrician, and a pediatric dietitian, using standardized instruments. All measurements were performed using the same device for each patient.

Data Collection Instruments

Height measurements were obtained with a precision of 0.1 cm, while the patients stood upright with their heads held straight and their eyes looking forward, and they were without shoes. The instrument used for this purpose was the (SECA 767 height gauge from Hamburg, Germany). Body weight

measurements were taken with (SECA 767 scales from Hamburg, Germany), while ensuring that the children wore only their undergarments, and measurements were recorded to the nearest 0.1 kg. Following the anthropometric measurements of the enrolled patients, total body composition measurements were conducted using the Tanita BC 418 device (TANITA Corporation, Maeno-Cho, Itabashi-ku, Tokyo, Japan). These measurements included total body muscle and fat mass (in kilograms), body fat percentage, and the quantities of fat and muscle in all extremities and the trunk. All measurements were taken in the morning after the patients had fasted and emptied their bladders. The BIA (Bioelectrical Impedance Analysis) component of the measurements took approximately 30 seconds for each participant. The BIA monitor used in this study provided separate measurements for FM (Fat Mass), FFM (Fat-Free Mass), and estimated SMM (Skeletal Muscle Mass) for both limbs and the trunk. Therefore, the sum of SMM in the four limbs (appendicular skeletal muscle mass, SMMa) was calculated.

Additionally, grip strengths for both the right and left hands were measured using the Camry EH101 hand dynamometer (Camry Corporation, Mongkong KLN, Hong Kong, China). After zeroing the dynamometer needle, the participant was asked to squeeze the device without it touching their body, and this process was repeated three times. The average values of the readings on the dial were recorded in kilograms (kg). The maximum grip strength of both hands was measured using a digital CAMRY (Camry Corporation, Mongkong KLN, Hong Kong, China) electronic hand dynamometer with a range of 1-90 kg. During the measurement process, the child holding the dynamometer was instructed to keep their arm at a right angle, place their elbow next to their body, and grip the dynamometer. The handle of the dynamometer was adjusted accordingly. The child was instructed to hold and grip the dynamometer with all four fingers on the handle and the thumb on the side, with the fingers wrapped around the handle. When ready, they were asked to squeeze the dynamometer with maximum isometric effort, and this grip was maintained for approximately 10 seconds. This procedure was repeated three times for both the right and left hands, resulting in three separate measurements for each hand. The averages of these values were calculated and recorded as the final measurement on the form. The highest value obtained in this process was used for calculations. During these measurements, no other body movements were allowed, and the individual was encouraged to exert maximum effort. The maximum hand grip strength was divided by BMI to calculate the grip strength to BMI ratio.

Sarcopenic Obesity Evaluation Methods

McCarty and Kim's studies (13,14) were used as references to define sarcopenia. In this method, BMI z-scores were divided into five intervals for boys and girls aged 6-8 and 9-10 separately. MFR was calculated by dividing appendicular skeletal muscle mass (SMM) by total body fat mass (BFM). The mean and standard deviation of the obtained

MFR were calculated for each fifth interval of the BMI z-score. An MFR equal to -2 standard deviations was found for the middle fifth interval of the BMI z-score. Sarcopenic obesity (SO) was defined as cases where the MFR value fell below the highest fifth percentile of the BMI z-score.

In McCarthy et al.'s study (13), they determined the muscle-to-fat ratio (MFR) by dividing the appendicular skeletal muscle mass (SMMa) by the fat mass (FM). They categorized the children into fifths of BMI z-scores within specific age ranges, separately for boys and girls. The mean and standard deviation (SD) of MFR were calculated for each fifth. For the first time, they established an MFR cut-off corresponding to -2 SD for the middle fifth. Sarkopenic obesity (SO) was defined as cases falling below this cut-off among children in the highest fifth of BMI z-scores. For children at risk of developing SO, the methods proposed by Gontarev and colleagues (17) were employed. In this method, the value obtained by dividing the measured maximum hand grip strength by the calculated BMI was calculated. BMI was determined as body weight divided by height squared (kg/m 2).

Ethical Aspects of the Study

Ethical approval for this study was obtained from the Gülhane Education and Research Hospital, Scientific Research Ethics Committee (Approval No: 2021-350).

Data Analysis

The distribution of all data was assessed using the Kolmogorov-Smirnov test. For normally distributed data, mean ± standard deviation was reported, while for non-normally distributed data, median and interquartile range (IQR) were used. These calculations were performed separately for both genders and the two age groups defined (6-8 years as Group 1 and 9-10 years as Group 2). Initially, descriptive statistics were conducted. Subsequently, Spearman correlation analysis was performed to compare MFR and grip-to-BMI between girls and boys within each age group, with p-values <0.05 considered statistically significant.

Thirdly, ROC curves were used to determine the ability of the grip-to-BMI ratio to predict the risk of sarcopenic obesity in children. In ROC curves, the Area Under the Curve (AUC) was calculated and interpreted as follows: 0.9-1.0 excellent; 0.8-0.9 good; 0.7-0.8 fair; 0.6-0.7 poor; and 0.5-0.6 fail ($p < 0.05$) (18). Fourthly, ROC analysis cut-off points for the grip-to-BMI ratio to define sarcopenic obesity were calculated separately for each gender and age category. The best cut-off point, balancing sensitivity and specificity, was defined as the cut-off point that yielded the smallest value for the equation = $(1\text{-sensitivity})^2 + (1\text{-specificity})^2$ (18). An age-adjusted binary logistic regression model was used to predict the likelihood of developing sarcopenic obesity based on the cut-off values in Grip-to-BMI. Effect sizes were reported as odds ratios (ORs), which are exponentials of the estimates. All analyses were conducted using the Statistical Package for the Social Sciences software (SPSS, v. 22.0; SPSS Inc., Chicago, IL, USA), and $p < 0.05$ values were considered statistically significant.

RESULTS

Among a total of 431 children, 230 (53%) were female, and 201 (47%) were male, with a median age of 8 (ranging from 6 to 10). In the 6-8 age group, there were 122 (53%) girls and 110 (47%) boys. Notably, the distribution of heights between both genders in this age range did not yield significant differences (p=0.587). However, within the 9-10 age group, a significant difference in height was observed between boys and girls (p=0.009).

Regarding weight, no significant differences were detected between both genders in the 6-8 age range (p=0.531). Conversely, in the 9-10 age group, there was a significant disparity in weight (p=0.010) (see Table 1 for descriptive statistics of children categorized by age group and gender).

Regarding the Body Mass Index (BMI), there were no significant differences between girls and boys in the 6-8 age group (p=0.645). However, in the 9-10 age group, a notable difference was observed (p=0.028) (see Table 1).

Tablo 1. Descriptive statistics of boys and girls

	6-8 Years			9-10 Years		
	Boys	**Girls**	**p value**	**Boys**	**Girls**	**p value**
N (%)	110(47)	122(53)		91(47)	108(53)	
Height (cm)	125,63±6,75	124,97±7,26	0,587*	137,96±7,24	135,29±6,83	**0,009***
Height sds	0.47±1.17	0.58±2.1	0.730	0.47±1.12	0.06±0.97	**0.016**
Weight (kg)	25,95(18,50-54,00)	25,85 (15,30-53,40)	0,531**	34,60 (20,90-68,30)	32,15 (20,60-63,00)	**0,010****
Weight sds	0.77±1.37	0.59±1.66	0.358	0.90±1.49	0.38±1.39	**0.013**
BMI (kg/m^2)	16,25(12,80-30,10)	16,75 (11,10-27,80)	0,645**	18,80 (12,80-32,50)	17,30 (13,50-31,20)	**0,028****
BMI sds	0.46 ±1.45	0.30±1.55	0.715	0.78±1.49	0.41±1.34	**0.054**
BFM (kg)	5,10 (2,70-22,10)	6,05 (2,30-19,30)	0,226**	8,50 (2,80-29,90)	7,30 (3,60-29,80)	0,518**
SMM (kg)	7,35 (4,10-14,80)	7,10 (3,40-11,50)	0,801**	10,80 (5,30-19,70)	9,35 (4,50-16,30)	**<0,001****
MFR (kg/kg)	1,31±0,36	1,19±0,31	**0,026***	1,31 (0,51-2,62)	1,18(0,49-2,11)	0,203**
Handgrip (kg)	11,25 (5,50-19,50)	10,20 (4,20-20,40)	**0,022****	15,70 (10,10-27,90)	13,75 (6,10-32,00)	**<0,001****
Grip-to-BMI ($kg/kg/m^2$)	0,64 (0,24-1,01)	0,61 (0,33-1,13)	**0,029****	0,77 (0,33-1,35)	0,72 (0,39-2,12)	0,088**
Sarkopenic obesity by MFR n(%)	17 (15.5)	9 (7.4)	0,051***	4 (4,4)	11(10.2)	0,123***

BMI: body mass index; BFM: body fat mass; SMM: skeletal muscle mass; MFR: muscle fat ratio. *:independent samples t-test; ** Mann-Whitney U test; ***Pearson chi-square test

In terms of Body Fat Mass (BFM) and Skeletal Muscle Mass (SMM), no significant differences were found in the 6-8 age group for both girls and boys (p=0.226, p=0.801). Conversely, in the 9-10 age group, while there was no significant difference in BFM (p=0.518), there was a significant disparity in SMM (p=0.001).

Muscle-to-Fat Ratio (MFR) showed a difference in both girls and boys in the 6-8 age group (p=0.026). However, this difference was not significant among children aged 9-10 (p=0.203).

In terms of handgrip strength, there was a statistically significant difference between boys and girls in both age groups (6-8 years: p=0.022, 9-10 years: p<0.001).

Lastly, the Grip-to-BMI ratio showed a significant difference in both boys and girls in the 6-8 and 9-10 age groups (p=0.029, p=0.088). The prevalence of sarcopenic obesity in girls was found to be 8.7%, while in boys, it was 10.4% (Table 1).

The relationship between Grip-to-BMI and MFR was low in girls and boys aged 6-8 years (r=0.363, r=0.458, p<0.001), while it was high among boys and girls aged 9-10 years (boys: r=0.628, p<0.001; girls: r=0.612, p<0.001) (Table 2).

Table 2. Spearman correlation between MFR and grip-to-BMI

	6-8 Years		9-10 Years	
	Boys	**Girls**	**Boys**	**Girls**
	MFR		**MFR**	
Grip-to-BMI	0,363*	0,458*	0,628*	0,612*

*: Correlation is significant at the level of p<0,001 (2-tailed)

In the study, cut-off values for MFR in the 3rd quintile using BMI were found to be ≤0.81 for 6–8-year-old girls, ≤0.78 for 9–10-year-old girls, ≤0.96 for 6–8-year-old boys, and ≤0.61 for 9–10-year-old boys. The Area Under the Curve (AUC) was 0.664 for 6–8-year-old boys, 0.702 for girls in the same age group, 0.957 for 9–10-year-old boys, and 0.820 for girls in the same age group, indicating the accuracy of the test in identifying children at risk of developing sarcopenic obesity. The cut-off points for Grip-to-BMI ratio were estimated as 0.564 for 6–8-year-old girls, 0.654 for boys in the same age group, 0.672 for 9–10-year-old girls, and 0.633 for boys in the same age group. The Grip-to-BMI cut-off points were found to be sensitive for both genders and age groups (Table 3).

Table 3. Evaluation of hand grip strength/BMI ratios in ROC analysis by age and gender

	AUC (95% CI)	p Value	Cut-off point	Sensitivity (%)	Specificity (%)	Equation
Boys (6-8 years)	0,664 (0,537-0,790)*	0,033	0,654	82,4	50,0	0,286
Girls (6-8 years)	0,702 (0,543-0,862)*	0,044	0,564	77,8	64,6	0,174
Boys (9-10 years)	0,957 (0,885-1,000)*	0,002	0,633	100,0	83,9	0,026
Girls (9-10 years)	0,820 (0,732-0,908)*	0,001	0,672	90,9	71,1	0,091

AUC: Area under the curve; 95%CI:95% confidence interval; Equation: (1-Sensitivity)2+(1-Specificity)2

For males, OR (95% CI): 11,705 (3.318-41,290), p < 0.001

For females , OR (95% CI) :11,833 (3,352 -41,757) p< 0,001

In the age-adjusted binary regression model, the odds ratio (OR) was 11,833 (95% CI: 3,353-41,757) with p< 0.001 for girls and 11,705 (95% CI: 3,318-41,290) with p<0.001 for boys. This demonstrates the relationship between the Grip-to-BMI ratio and the risk of developing sarcopenic obesity.

DISCUSSION

This study presents significant findings regarding the impact of the COVID-19 pandemic on child health. The research involved 431 Turkish children aged 6-10 years, utilizing bioelectrical impedance analysis (BIA) to estimate body fat percentage and skeletal muscle mass. Notably, the study highlighted the grip-BMI ratio as an effective tool for identifying risk of sarcopenic obesity in children. By applying BIA to estimate body composition indicators amongst a sample of young participants, the study provides valuable insights. It suggests the grip-BMI ratio warrants consideration as a screening metric to identify at-risk pediatric demographics.

The Grip-to-BMI ratio demonstrated its efficacy in identifying SO risk, with impressive Area Under the Curve (AUC) values. Among 6-8-year-olds, AUC values were 0.702 for girls and 0.664 for boys. For 9-10-year-olds, these values rose to 0.820 for girls and an impressive 0.957 for boys. The research determined optimal cutoff points for the Grip-to-BMI ratio for 6-8-year-old boys and girls, offering sensitivity rates of 82.4 % and 77.8 %, and specificity rates of 50% and 64.6%, respectively. In the 9-10 age group, sensitivity rates were exceptionally high at 100% for boys and 90.9% for girls, with corresponding specificity rates of 83.9% and 71.1%. Importantly, this study sheds light on the pandemic's effects on child health. It contributes to a better understanding of how the COVID-19 pandemic, with its disruptions

to daily routines, such as reduced physical activity and altered dietary habits, may have contributed to the emergence of SO in children.

The COVID-19 pandemic significantly impacted the children's daily routines and resulted in important alterations to body composition. Research has shown that the pandemic's impact, characterized by reduced physical activity, increased stress, and altered dietary habits, may lead to increased fat accumulation in children. One study analyzed the implications of the COVID-19 pandemic on variations in body composition, revealing differences in body mass index (BMI), body fat proportion (%fat), and BMI z-scores (19). In addition, Azoulay et al. observed an improvement in the muscle-fat ratio among participants of low and normal weight but found the ratio remained relatively stable in overweight/obese individuals (20). Specifically, the research undertaken by Azoulay and associates examined alterations in body composition ratios across weight groupings of pediatric members during the pandemic. They found lean and healthy weight children exhibited enhanced muscle-fat percentages compared to pre-pandemic levels. However, overweight and obese youth did not exhibit considerable fluctuation in their muscle-fat percentages. Fäldt et al. noted a rise in BMI, particularly in lower socioeconomic status regions, among 3-4-year-old children in Sweden during the pandemic period. Bergmann et al. stated that parents of overweight children perceived increases in body weight and declines in physical activity levels throughout the phase of social segregation. In summary, studies have indicated that the COVID-19 pandemic has led to adverse changes in body composition in children, marked by an increase in body fat and BMI (20-22).

Another study carried out in the Czech Republic revealed that the existing obesity and overweight issues in boys aged 9-11 were exacerbated by the restrictions related to COVID-19 (23). In a study conducted in Turkey, the frequency of overweight and obesity in Isparta province during the COVID-19 pandemic was determined to be 26.5%. This research also recognized a rise in BMI among 9-10-year-old boys and girls. Both within Turkey and worldwide, elements such as limitations on school attendance and the transition to online learning, suspension of sports, and a shift to a more sedentary way of life, combined with increased snacking throughout the day because of lockdown restrictions, could have contributed to this emerging trend. By identifying distinct patterns in body composition responses within various pediatric weight categories, the results offer valuable insights into how the lifestyle adjustments required during the pandemic had varying effects on individuals, depending on their initial levels of adiposity. The findings indicate that leaner children demonstrated advantages in terms of preserving relative skeletal muscle mass, while excess weight may have hindered similar adaptations in overweight or obese youth. In general, this research provides valuable insights into the diverse effects of societal lockdowns and

changes in activity levels on the body composition of pediatric individuals.

While sarcopenia is commonly associated with age-related muscle decline, recent research suggests that pediatric populations may also be susceptible to sarcopenia as a result of obesity and sedentary lifestyles. The term "sarcopenia," derived from the Greek words "sarx" for flesh and "penia" for loss, was first coined by Rosenberg in 1989 to describe the reduction of muscle mass in the elderly population (24). Additionally, "Sarcopenic Obesity (SO)" is defined as a condition characterized by decreased muscle mass along with excessive fat accumulation (25). Sarcopenic Obesity (SO) has been studied primarily in the elderly population. However, research has demonstrated its potential development in children. SO is linked to insulin resistance and metabolic disorders among children (26-27). This condition results from the release of certain hormones and chemicals in the abdominal cavity, including adipokines. These substances play a pivotal role in inducing inflammation, subsequently causing insulin resistance and distinct metabolic effects in individuals with Sarcopenic Obesity (SO) (6). Furthermore, myosteatosis and mitochondrial dysfunction have been identified as underlying factors contributing to muscle weakness and fatigue in individuals with SO (28).

Various methods have been employed in studies to diagnose Sarcopenic Obesity (SO). Gontaraev (17) and Steffi (31) utilized a combination of Bioelectrical Impedance Analysis (BIA) and dynamometry, whereas Gatjens (30), McCarthy (13), and Stefanaki (29) exclusively relied on BIA. In our research, we employed both BIA and hand dynamometry for diagnosis. Furthermore, there are discrepancies among the samples used in these studies. Gontarev utilized a healthy group aged 6-10 years, Steffi examined a healthy adolescent population aged 4-14 years, Gatjens and McCarthy investigated healthy adolescents aged 5-18 years, and Stefanaki et al. exclusively included overweight children in their study. This study exclusively included completely healthy children aged 6-10 years. The most notable aspect of this study is that it was conducted exclusively during the period of the COVID-19 pandemic, and the study sample included only healthy, prepubertal children. Hence, the differences in the prevalence of sarcopenic obesity (SO) between studies may be related to these different factors.

In studies assessing body composition using the Bioelectrical Impedance Analysis (BIA) method with the MFR - 2 SD, the prevalence of Sarcopenic Obesity (SO) has been found to be 7.2%, 8.31%, and 9.2% among boys aged 5-10 years and 5.66%, 5.9%, and 9.3% among girls aged 5-10 years.

In this study, using the method of McCarthy and colleagues, the prevalence of Sarcopenic Obesity (SO) was found to be 15.5% among boys aged 6-8 years, 7.4 % among girls in the same age group, 4.4% among boys aged 9-10 years, and 10.2% among girls in the same age group. The decline in physical activity and the rise in food consumption observed during the COVID-19

pandemic appear to play pivotal roles in the reduction of muscle mass and the augmentation of body fat mass, subsequently impacting the development of SO.

The BIA technique, which was also employed in this study, was initially described in the 1960s and became widely recognized in the 1980s. Over the years, various other methods have been used for the diagnosis of Sarcopenic Obesity (SO), considering both cost-effectiveness and ease of use. In this regard, Cruz-Jentoft et al. (12) recommended the use of handgrip strength for the diagnosis of sarcopenia. Utilizing handgrip strength in children to determine the risk of Sarcopenic Obesity (SO) may offer a beneficial and practical approach for field studies, considering the use of specialized equipment and expensive procedures. As body fat percentage increases alongside obesity and MFR decreases, muscle strength likely diminishes.

Relative muscle strength assessment may provide a practical alternative to bioelectrical impedance analysis (BIA) for identifying pediatric patients vulnerable to SO. Sarcopenia has historically referred to age-related muscle depletion in older adults. However, recent evidence indicates that physical inactivity during childhood can also induce sarcopenia. Measurement of muscle strength could help detect declining muscle mass and function in sedentary youth at risk of concurrent adiposity. Early identification of SO predisposition through readily available strength tests may enable timely lifestyle interventions to mitigate future health complications. More research is still needed to validate relative strength as a screening tool for childhood SO compared to modalities such as BIA (14). Notably, Gontarev et al. conducted a study involving 4021 children in Macedonia and determined Grip-to-BMI ratios within the range of 0.826 to 0.859 for boys (95% CI) and 0.752 to 0.789 for girls. In a separate study by Steffi and colleagues, which included 730 children in the Czech Republic, Grip-to-BMI ratios were found to be 0.791 for girls aged 4-9, 0.789 for girls aged 10-14, 0.719 for boys in the 4-9 age group, and 0.896 for boys aged 10-14 (31). In contrast, our study exclusively enrolled 431 participants during the COVID-19 lockdown period, setting it apart from previous research. During this unique timeframe, we observed Grip-to-BMI ratios of 0,664 (95%CI 0,537-0,790) for boys and 0,702 (95%CI 0,543-0,862) for girls aged 6-8 and 0,957 (95% CI 0,885-1,000)for boys and 0,820 (95%CI 0,732-0,908) for girls aged 9-10. It is plausible that the variations in Grip-to-BMI ratios observed in our study result from significant lifestyle changes amid the COVID-19 pandemic. These lifestyle modifications are consistent with recognized factors that have a negative effect on muscle strength and contribute to increased adiposity over a period of time. This correlation is likely responsible for the differences observed in Grip-to-BMI ratios between our study and previous research conducted prior to the pandemic.

The main finding of our study aligns with our hypothesis, indicating that the grip-to-BMI ratio effectively distinguishes children at risk of sarcopenic obesity from those who are

not. This suggests that the grip-to-BMI ratio could serve as a valuable screening method applicable in field settings.

While the underlying causes of sarcopenia differ between children and the elderly, insufficient physical activity and poor nutrition emerge as significant risk factors for pediatric sarcopenia. Previous research has linked low activity levels, particularly on weekends, to unfavourable body composition in children aged 6-8. The COVID-19 pandemic likely heightened the risk of sarcopenia in children due to decreased physical activity during remote schooling and increased sedentary behaviour (32-33). These environmental conditions, coupled with disrupted nutrition, created a conducive setting for the development of sarcopenic obesity.

The grip-to-BMI ratio offers a practical diagnostic approach by identifying at-risk children through a simple measurement, normalized by BMI. This method is advantageous, considering potential barriers to healthcare access during crisis periods. While not conclusive, the grip-to-BMI ratio provides a cost-effective and efficient initial screening tool to identify children requiring further medical evaluation, nutritional guidance, or exercise therapy to address emerging sarcopenia and prevent future health complications. Therefore, the grip-to-BMI ratio exhibits promise as a suitable field-based metric deserving application in various pediatric populations.

The research sheds light on the effects of the COVID-19 pandemic on child wellness. It demonstrates how disruptions to daily routines introduced by the pandemic, particularly decreased physical activity and altered dietary habits, may have contributed to the development of sarcopenic obesity. Specifically, reduced opportunities for exercise due to lockdowns and school closures, coupled with potential changes in nutrition during this period, could have negatively impacted body composition in children.

By applying BIA to estimate body composition indicators amongst a sample of young participants, the study provides valuable insights. It suggests the grip-BMI ratio warrants consideration as a screening metric to identify at-risk pediatric demographics. Overall, the findings enhance understanding of the pandemic's potential downstream health consequences and inform efforts to address related public health challenges going forward.

LIMITATIONS

One limitation of the study is that it only included participants from a single region in Turkey, which may restrict the generalizability of the findings. The findings of this study may not accurately represent the prevalence of sarcopenic obesity among 6-10-year-old Turkish children in other regions of the country. To enhance the generalizability of the results, future research should involve larger sample sizes and include participants from diverse geographical locations within Turkey. This would provide a more comprehensive understanding of the prevalence and characteristics of sarcopenic

obesity in this specific age group across the country.

CONCLUSION

The study findings suggest that the grip-to-body mass index (BMI) ratio could be a valuable tool for early diagnosing and managing sarcopenic obesity risk. Furthermore, they indicate that the alterations resulting from the COVID-19 pandemic in children may adversely affect the development of sarcopenic obesity. However, the acquired data will contribute to comprehending and monitoring the pandemic's effects on children's health. The utilization of the grip-to-BMI ratio as a straightforward method for early identification and management of children susceptible to sarcopenic obesity is recommended. Nevertheless, long-term investigations in this domain are imperative.

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