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MORPHOLOGICAL CHARACTERISTICS AND HEALTH STATUS OF 8-19-YEAR OLD GIRLS

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ABSTRACT
Factors influencing health and well-being of children and adolescents are related to their morphological characteristics and health status. Anthropometric and morphological parameters correlate with children's health, well-being, physical activity, and self-esteem. Therefore, the aim of this study was to analyze the factors with the most significant impact on the body composition and health status and to evaluate overweight and obesity levels of girls and adolescents between the ages of 8 and 19 by using WHO references. This study included 202 girls with a mean age of 12.1 ± 3.5 years, mean height of 150.1 ± 15.0 cm, and mean BMI of 18.8 ± 4.0 kg/m². All of the participants were assessed by using the InBody120 body composition analyzer. Principal component factor analysis, using body height as a selection variable, was used in order to determine the main factors related to health status of children and adolescents. The factor analysis identified three main factors: (1) anthropometric parameters of obesity; (2) morphological characteristics; (3) age and metabolism. In conclusion, the anthropometric parameters of obesity had the most significant impact on the analyses of the body composition and health status in children and adolescents.

Keywords: *anthropometry, adolescents, health status, height, factor analysis*

INTRODUCTION

Changes in lifestyle, associated with constant use of digital technologies in all areas of social activity and communication, have had a significant impact on the health-related physical fitness of children and adolescents. The wide-spread of online learning influenced by Covid-19 lockdowns was a main factor for reducing physical activity of school children with little or no Physical Education and sports classes, and at the same time increasing their screen time and sedentary behavior. This has been well-documented by a number of authors who outlined the negative impact of the pandemic on children's physical activity (Galle et al., 2020; Gobbi et al., 2020; Lopez-Gil et al., 2021; Bronikowska et al., 2021; Daniel, 2020; Zheng et al., 2020), in addition to the fact that most children and adolescents did not reach the recommended by the WHO physical activity guidelines of 60 min of physical activity per day even before the COVID-19 pandemic (Konstabel et al., 2014). Physical activity during youth is essential for adolescent's health and wellbeing, and therefore its reduction could have harmful effects in later life (Scheerder et al., 2006). One of the most common effects which have been reported in relation to reduced physical activity in children and adolescents include negative changes in body composition, increased obesity levels, depression, social isolation, decline in metabolic and immunological functions, and others (Jakobsson et al., 2020; Hwang et al.; Stockwell et al., 2021). Reported results indicated that the physical activity patterns of children are significantly related to their physical fitness (Tremblay et al., 2016). Therefore, health-related studies on morphological and anthropometrical parameters in children and adolescents are of a significant interest in the current pandemic and post-pandemic conditions.

The assessment and evaluation of body composition in children and adolescents are mainly undertaken for two reasons: to observe the relationship between anthropometric and morphological parameters in relation to physical fitness and in relation to health and wellbeing (Kilani & Abu-Eisheh, 2010; Bjelica et al., 2021). Overweight children and adolescents with low physical activity levels tend to transfer these negative outcomes in later life (Dietz et al., 2007), and it has been reported that fat accumulation during childhood contributes to becoming overweight in adulthood (Gültekin, Dasgupta & Özer, 2014). For those reasons, it has been recommended to monitor and evaluate body composition at young ages (Espana-Romero et al., 2010; Ruiz et al., 2010; Ortega et al., 2015; Cvejic, Pejovic & Ostojic, 2013; Seefeldt & Vogel, 1989).

One of the most important anthropometric parameters providing useful information about the process of growth and maturation of the child's body are body height, body weight, and body mass index (BMI). The BMI is calculated as body

weight divided by height in meters squared, and it has been widely applied to classify children's weight as underweight, normal, overweight or obese (WHO, 2000; Flegal, Tabak & Ogden, 2006; Pekar, 2011; Keys et al., 2014). However, the BMI does not distinguish between fat and muscle tissues (Chatterjee, Bajpai & Gerdes, 2021; Bogin & Varela-Silva, 2012). Another limitation of the BMI is that its value varies significantly at young ages (Cole, Freeman & Preece, 1995; Cole, Bellizzi, Flegal & Dietz, 2000; Holford & Colson, 2008), and the criteria used to evaluate children's BMI are different from that for adults. The value of children's BMI is compared against reference charts for the same age and gender, and then transformed into a percentile or Z-score (Flegal, Tabak & Ogden, 2006). One of the most popular international BMI reference charts for children and adolescents are those produced by the World Health Organization (WHO, 2007).

The utilization of adequate statistical methods can provide further clarity on the importance of growth parameters, such as body weight and height, and their relationship with the health and physical activity levels of children and adolescents. Therefore, the aim of this study was to analyze the main factors which have the most significant impact on the body composition and health status, as well as to evaluate overweight and obesity levels of girls and adolescents between the ages of 8 and 19 by using WHO references.

METHODS

This study consisted of 202 girls and adolescents from 8 to 19 years of age (mean age of 12.1 ± 3.5 years) from different schools in Sofia, Bulgaria. The sample of students was obtained according to the needs of the study and the accessibility of the participants. All participants were engaged in similar levels of physical activity and PE lessons.

An informed consent form was obtained from the parents of the participants prior to the study intervention, and the study was undertaken in accordance with the ethical standards established in the Declaration of Helsinki for Human Research (WMA, 2013).

Body height was measured to the nearest 0.1 cm by using SECA height measure. A standardized protocol for analyses with the InBody120 body composition analyzer was used for all participants. The portable analyzer uses a direct segmental multi-frequency bioelectrical impedance analysis method (DSM-BIA) with two different frequencies (20 kHz, 100kHz) at a total of five body segments (right arm, left arm, trunk, right leg, and left leg).

The following parameters were recorded: Body Mass Index (BMI), weight, body fat mass (BFM), present body fat (PBF), waist-to-hip ratio (WHR), growth score, obesity degree (normal range between 90-110), protein, minerals, fat free mass (FFM), skeletal muscle mass (SMM), total body water (TBW), and basal metabolic ratio (BMR).

Participants were measured in the morning on an empty stomach, bear feet, wearing shorts and T-shirts. All of the measurements and assessments were conducted in the sports lab at the Center for Scientific and Applied Activity in Sports, National Sports Academy, Bulgaria.

The statistical analyses were conducted by using SPSS 20.0, IBM, USA software. The analyses were based on the total of 202 participants by using descriptive statistics and principal component factor analysis with rotated component matrix (Varimax with Kaiser Normalization). Body height was chosen as the selection variable to determine the factors related to morphological characteristics and health status of children and adolescents.

RESULTS AND ANALYSIS

The recorded parameters of all participants in this study are presented in Table 1. The coefficient of variation was very good (CV ≤ 10) for the parameter height and WHR; good (CV 10-20) for growth score and obesity degree, and acceptable for (CV 20-30) age, BMI and BMR. The mean BMI of the 8-19-year-old girls was 18.8 ± 4.0 kg/m^2, which was within the 'normal' weight category (18.5–24.9 kg/m^2) defined by the WHO (WHO, 2000). The BMI Z-scores were calculated based on the WHO references for children and adolescents between the ages of 5 and 19 years of age, where normal Z-score is defined between -2SD and 1SD, overweight is >1SD and <2SD, obesity >2SD, and thinness > -2SD (WHO, 2007). The individual BMI Z-scores of the children in our study showed that 73.8% of the girls were within the 'normal category', 3.5% were assessed as 'thin', 17.3% were 'overweight', and 5.4% were 'obese'.

Table 1. *Anthropometric and morphological parameters of the 8-19-year-old girls*

Parameters	Mean ± SD	Coefficient of Variation
Age [years]	**12.1** ± 3.5	28.9
Height [cm]	**150.1** ± 15.0	10.0
Weight [kg]	**42.5** ± 15.0	35.4
BMI [kg/m2]	**18.8** ± 4.0	21.0
Total Body Water [L]	**24.1** ± 7.9	32.7
Protein [kg]	**10.3** ± 9.5	92.2
Minerals [kg]	**8.3** ± 13.4	160.6
Body Fat Mass [kg]	**9.1** ± 5.5	60.8
Fat Free Mass [kg]	**25.8** ± 13.9	54.0
Skeletal Muscle Mass [kg]	**15.3** ± 6.1	39.6
Percent Body Fat [%]	**21.0** ± 8.2	38.8
Basal Metabolic Ratio [kcal/24h]	**1080.1** ± 232.4	21.5
Waist-to-Hip Ratio	**0.81** ± 0.05	6.1
Growth Score [points]	**88.9** ± 16.1	18.1
Obesity degree	**95.2** ± 17.3	18.2

In addition, the individual BMI Z-scores for girls between the ages of 8-11 and 12-19 were also analyzed due to the specific differences in growth and physical development in those age brackets. The results showed that 77% of the girls between 8 and 11 were assessed within the 'normal category', 13% were 'overweight', 7% were 'obese', and 3% were 'thin'. In the group of girls between the age of 12 and 19, around 80% were with 'normal' weight, 17% were 'overweight', 2.4% were 'thin', and none of them were 'obese'. The lack of any obese children in this age bracket is probably due to the higher level of physical activity reported in the older girls, including an average of 3 training sessions a week.

The factor analysis component matrix is presented in Table 2. The analysis identified three factors which were named depending on the anthropometric, morphological, age- and metabolic-related parameters included in them (with a factor score above 0.700). The three factors derived from the correlation matrix had a total of 95.48% explained variance. The first factor accounted for 59.2%, which was the largest possible variance in the data set. The second factor accounted for 29.6% and the third for 6.6%.

Table 2. *Factor analysis of the anthropometric and morphological parameters for 8-19-year-old girls*

Parameters	Factor 1	Factor 2	Factor 3
Age	.004	-.078	-.786
BMI	**.834**	.220	.503
Weight	**.816**	.306	.488
Total Body Water (TBW)	.342	.079	**.862**
Protein	-.099	**-.992**	.062
Minerals	-.119	**-.993**	-.007
Body Fat Mass (BFM)	**.891**	.273	.314
Fat Free Mass (FFM)	.205	**.945**	.238
Skeletal Muscle Mass (SMM)	.231	**.908**	.321
Percent Body Fat (PBF)	**.888**	.312	.216
Basal Metabolic Rate (BMR)	.345	.110	**.858**
Waist-to-Hip Ratio (WHR)	**.942**	.096	.170
Growth Score	**-.922**	.146	.232
Obesity degree	**.815**	.308	.488

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

The first factor was named 'anthropometric parameters of obesity', and it included the following: BMI, weight, BFM, PBF, WHR, growth score, and obesity degree index. This factor accounted for more than half of the variance of the data set. The second factor was named 'morphological characteristics' including the following recoded parameters: protein, minerals, FFM, and SMM. The third factor was named 'age and metabolism' and it included age, TBW, and BMR.

DISCUSSION AND CONCLUSION

The factor analysis of the anthropometric and morphological parameters of the children and adolescents in our study identified three main components related to their health status.

The first one included mostly body composition parameters, and accounted for more than half, 56% of the variance in the data set. The parameter with the highest value (0.94) within the first factor was WHR (Table 2). The WHR represents the circumference of the waist to that of the hips, and a value above 0.85 in women is considered abdominal obesity (Andreacchi et al., 2013; Wright et al., 2021). In our study, 21 girls (around 10% of the sample) were evaluated with abdominal obesity but at the same time these subjects had a normal BMI. This is probably because of the limitation of the BMI assessment. Furthermore, studies indicated that the location and amount of fat, rather than overall adiposity, are much more informative for predicting obesity, cardiometabolic disease, and cancer (Pulit et al., 2019). Therefore, the BMI assessment should be utilized in a combination with other methods for evaluating body composition.

The parameter with the second highest value in the first factor was growth score (-0.92). In essence, the growth score includes body composition, obesity degree, height and weight, and it helps to establish the growth stage of children and adolescents (InBody120, 2022).

Body fat mass and percent body fat were the third and fourth parameters with the highest values, respectively (Table 2). Both parameters possess a great importance for the health and wellbeing of children in the later stages of their adult life. The findings of a comprehensive review including longitudinal studies showed that a higher level of healthy body composition with less fat mass in childhood is associated with a healthier cardiovascular profile and with a lower risk of developing diseases in adulthood (Ruiz et al., 2009).

The last two parameters with a high value in the first factor from our study were BMI and weight. They are both widely used in the classifications of normal body weight. BMI was recommended as an index of underweight for screening out children who are malnourished (Lohman & Going, 2006), and low body weight in children in sport, below the age- and gender-related norms, was reported as the most significant factor in delaying the onset of puberty (Georgopoulos et al., 2004).

The second factor (morphological characteristics) accounted for 29.6% variance in the data set, and it included parameters such as minerals, protein, FFM and SMM. The parameter with the highest value in the second factor was the amount of minerals (Table 2). It was reported that minerals account for around 4% of the body weight (McArdle, Katch & Katch, 2015). The second highest parameter in the morphological characteristics factor in our study was the amount of proteins, which are essential for the body to repair cells and make new ones. The third and fourth parameters with high value were FFM and SMM. The primary component of FFM is SMM, which is the force generating tissue of the body (Malina et al., 2013). FFM have been also used in the literature to calculate fat-free mass index (FFMI, FFM/height^2) and fat mass index (FMI; FM/height^2) (Hattori, Tatsumi & Tanaka, 1997). Both indexes were utilized to assess body composition in diabetes adolescent girls (Chung et al., 2015). It has been reported that FFM in a combination with low PBF are used as criteria in training sessions to achieve ideal body composition related fitness (Kilani & Abu-Eisheh, 2010).

The third factor in our study was linked with age and metabolism, and it accounted for the lowest variance in the data set (around 7%). The parameters included in this factor were age, TBW and BMR, from which TBW had the highest value (Table 2). TBW content decreases with age, with newborns having the highest water content. TBW accounts for 40-60% of human body weight, and around 74% of muscle tissue and 50% of fat tissue is water Moreover, water is vital for the human body because it is involved in the metabolic and thermoregulatory processes. Furthermore, of the total

body water, around 62% is intracellular and 38% is extracellular (McArdle, Katch & Katch, 2015).

For the calculation of our study BMR was determined by using the InBody120 body composition analyzer applying a regression equation based on FFM (InBody120, 2022). BMR is the minimum energy required to maintain the body's vital functions at rest, and our results showed that BMR was correlated with the other anthropometric and morphological parameter: height (r = .897); age (r = .790); BMI (r = .700); weight (r = .950); TBW (r = 1); SMM (r = .700); FFM (r = .200); WHR (r = .570); growth score (r = .380); obesity (r = .400) ; protein (r = .600); Minerals (r = .500); BFM (r = .500). BMR is affected by FFM, and in people with higher amount of FFM, the basal metabolic rate is much higher, which means that more kilocalories are needed for vital body functions at rest.

In our study, a total of 20% of the girls between the ages of 8 and 11 were assessed as overweight (13%) or obese (7%), and 17% of the female adolescents between 12 and 19 years of age were overweight with zero obese subjects. These findings were lower than the observed values by other researchers, which ranged from 30% to 45% of overweight/obesity frequency in children (Guinhouya, Apete & Hubert, 2009; Sanchez-Vaznaugh, 2015). Nevertheless, 20% is still a high number (2 out of every 10 children) considering that excessive weight above the WHO norms not only limits performance but it also possesses a risk of developing diseases in adulthood.

In conclusion, the anthropometric parameter height showed a strong relation with the other parameters from the analysis of body composition. The strongest relation of height was reported with the parameters from the first factor (anthropometric parameters of obesity). The anthropometric parameters of obesity had the most significant impact on the analyses of the body composition and health status of the children and adolescents in our study.

Although the second and the third factors accounted for much less variance in the data set, they determine the structure of the human body, and they are influenced by lifestyle, diet, and exercise. Therefore, all three factors are important in building the morphological characteristics of children and adolescents. At the same time, they should be considered in the context of the overall health status and well-being of the subjects.

Our results raise the question of the dynamics and the relationship between the parameters that are most relevant to the health of children nowadays. This study provides the basis for conduct new, similar research, and comparisons of some age- and gender-related characteristics. At the same time, future cross-cultural research would be of a great interest in order to identify differences in the parameters studied in terms of certain national, social and demographic characteristics.

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