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Analysis of Differential Indicators for Childhood Obesity Risk Assessment

Biljana Trajkovski[1], Sanja Ljubičić[1], Tena Pejčić[1], Grgur Višić[2]

[1]International University of Rijeka, Faculty of Teacher Education, Rijeka, Croatia, [2]University of Zagreb, Faculty of Kinesiology, Department of General and Applied Kinesiology, Zagreb, Croatia

Abstract

Analysis of children's morphological characteristics is crucial for monitoring their growth, maintaining general health and identifying problems such as overweight or obesity. The aim of this study was to determine the differentiation of obesity risk indicators by gender and chronological age in children of early school age. The study involved 357 children (8.63±1.15 years) of whom there were 180 boys (8.79±1.14 years) and 177 girls (8.46±1.13 years) from three primary schools in Rijeka. A set of variables in which the research analysis was carried out, three indicators of the subjects' body structure were calculated: body mass index (BMI), subcutaneous fat (FAT)and waist-hip ratio index (WHR). The results indicate that indicators of risky health conditions such as body mass index, subcutaneous fat and WHR index are increasingly stable and serious with the increase in the chronological age of children. The MANOVA for the total sample indicated a significant effect of class on the combined dependent variables (BMI, FAT, WHR, WHtR) with Wilks' Lambda=0.628; $F(12, 894.55)=11.61$; $p<0.001$. A significant difference between girls and boys was also found. Girls have lower BMI values ($t(345)=3.12$; $p=.002$), FAT ($t(279)=2.41$; $p=.017$), WHR ($t(353)=3.58$; $p=.000$) as well as WHtR values ($t(344)=-3.07$; $p=.002$) compared to boys. In conclusion, the study demonstrates that as children's chronological age increases, obesity risk indicators such as BMI, subcutaneous fat, and WHR become more pronounced, with boys exhibiting higher values in all indicators compared to girls.

Keywords: *children, obesity, health, education*

Introduction

Morphological anthropometry is applied to evaluate morphological characteristics. Anthropometric references are useful tools for assessing the general health and growth process of children and adolescents (Soylu et al., 2021). Analysis of morphological characteristics in children is crucial for monitoring their growth, maintaining general health and identifying problems such as overweight or obesity. For example, children who grow up with an optimal body weight are more likely to maintain it over the years (Dietz, 1998). Therefore, it is important to emphasize the critical periods between childhood and early adolescence as a fundamental point in school curricula (Zvonar, Štefan, Kasović, & Piler, 2022). Research on the physical development of children in early school age provides valuable data that enable the identification of risk groups or even timely recognition and guidance of children in certain sports disciplines. (Malina, Bouchard, & Bar-Or, 2004).

Recent research results clearly indicate a serious problem of obesity among children (Bjelica, Katanić, Ćorluka, Gardašević & Pehar, 2021; Katanić et al., 2021; WHO, 2023). Namely, every fourth child faces this health challenge, with a special emphasis on children from coastal areas who show significantly higher values in this context (Bjelica et al., 2021). Furthermore, data indicate that a third of school children are overweight (Katanić et al., 2021), and body mass index values show a negative upward trend for both sexes, highlighting the worrying increase in obesity among children during the first four grades of primary school (Tomac, Šumanović, & Prskalo, 2012). Recent research also shows high genetic correlations that underlie the structure of the human body, indicating the

Correspondence:

Grgur Višić
University of Zagreb, Faculty of Kinesiology, Department of General and Applied Kinesiology, Horvaćanski zavoj 15, 10 000 Zagreb, Croatia
E-mail: grgurvisic@gmail.com

existence of gene sets that influence anthropometric traits (Silventoinen et al., 2023). Anthropometric methods used to assess nutritional status include measuring body weight, body height, circumference (waist and hips), as well as indices such as body mass index, waist-hip ratio (WHR), and waist-body height (WHtR) (Malczyk, 2016).

A better knowledge of genetic variants, eating habits, physical activity levels and other factors can help to understand the development of obesity and other features of the human body. Determining the current state of the body structure indicators of school-age children enables early detection of potential problems in physical development, which can prevent long-term health problems (Kohl & Cook, 2013). Therefore, the aim of this study is to determine the differentiation of obesity risk indicators by gender and chronological age in children of early school age, highlighting the critical role of morphological anthropometry in identifying obesity risk factors, enabling early detection of potential health issues, and providing data to guide effective interventions that promote long-term health.

Methods

Sample of respondents

The research was conducted in three primary schools in Rijeka. The participants were children of early school age, a total of 357 children (177 girls and 180 boys). On average, boys are 8.79±1.14 years old, with a height of 140.35±9.20 cm, weight of 35.35±10.47 kg, and BMI of 17.68±3.79. In comparison, girls are slightly younger at 8.46±1.13 years, with an average height of 136.28±8.99 cm, weight of 31.13±7.72 kg, and BMI of 16.57±2.76.

Sample of variables

The research analysis focused on a set of variables that included three indicators of body composition for both male and female students: body mass index (BMI), subcutaneous fat (FAT) and WHR index (WHR). Firstly, body height was measured with Martin Anthropometer in the "Frankfurt horizontal" position (Takei Scientific Instruments Co. Ltd., Niigata-City, Japan); body weight was assessed through the TANITA diagnostic scale (BC-720) (Tanita Corp., Tokyo, Japan); body fat was measured by Lange calliper (Lange, Cambridge Scientific Industries, Cambridge, MD); waist and hip circumference were measured using a standard flexible but non-stretchable tape. Body mass index (BMI) was calculated as the ratio of body mass (kg) to the square of height (m²). Subcutaneous fat was assessed by averaging two skinfold measurements: one from the back and one from the upper arm. The waist-to-hip ratio (WHR) was determined by dividing waist circumference by hip circumference, while the waist-to-height ratio (WHtR) was calculated by dividing waist circumference by height.

Description of the research protocol

The research was approved by the Department of Methodologies of Natural and Social Sciences Subjects of the Faculty of Teacher Education in Rijeka and the Council of Teachers of the visited Primary Schools in Rijeka. The research was conducted in accordance with the Code of Ethics for Children. Parents and children are familiar with the necessary information related to the research, and the parents have signed a consent in which they have given consent for the participation of children in the research. Measurements were conducted in April 2023 following the guidelines of the International Biological Program (IBP) (Weiner & Lourie, 1969). Nutritional status was categorized based on the reference values established by Cole et al. (2000), which classify individuals as having optimal body weight, being overweight, or being obese.

Statistical data processing

Statistical data analysis was performed using the Statistica 12 software (Stat Soft Inc., Tulsa, OK, USA). To assess differences in average scores between boys and girls, an independent samples T-test was employed. Multivariate analysis of variance (MANOVA) and Tukey's post hoc test were utilized to compare the groups (Classes 1, 2, 3, and 4) within the total sample and within boys and girls separately. Statistical significance was determined at the $p<0.05$ level. The results are presented in tables and graphs.

Results

The distribution of children's nutritional status shows a steady rise in the prevalence of overweight and obesity as chronological age increases. The highest proportion of children classified as having optimal nutrition is found in first grade (87.84%). Conversely, the largest percentage of overweight children is observed in fourth grade (18.35%), while the highest prevalence of obesity occurs in third grade (8.97%). The first grade exhibits the lowest rates of overweight (9.46%) and obesity (2.7%).

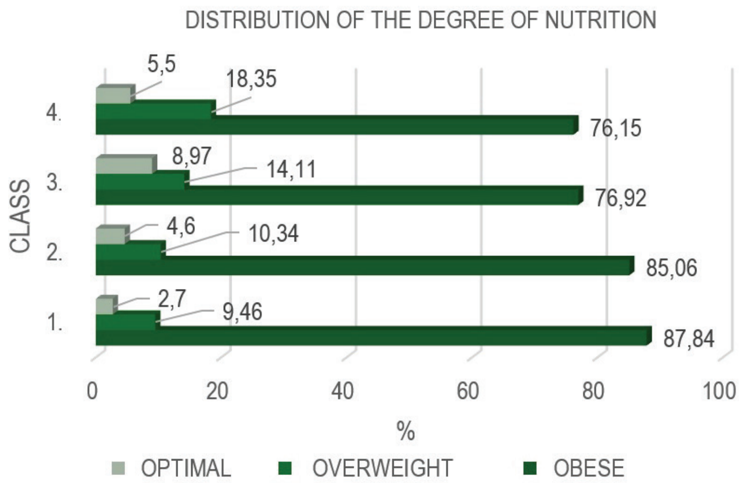

FIGURE 1. Distribution of nutritional status

In Table 1, the T-test for independent samples was calculated. A significant difference between boys and girls was found in all observed variables. Girls have lower BMI values (t(345)=3.12; p=.002). FAT (t(279)=2.41; p=.017), WHR (t(353)=3.58; p=.000) as well as WHtR values (t(344)=-3.07; p=.002) compared to boys.

Table 1. T-test for independent samples based on gender

Variable	Boys	Girls	t-value	p
BMI (kg/m^2)	17.68	16.57	3.12	0.002*
FAT (mm)	14.06	12.60	2.41	0.017*
WHR (cm)	0.89	0.87	3.58	0.000*
WHtR (cm)	0.47	0.45	-3.07	0.002*

Legend: AS_M – the arithmetic means of the boys; AS_F - the arithmetic means of girls; t – t-values; df – degrees of freedom; p – p-value; BMI – body mass index (kilograms/meters^2); FAT – subcutaneous adipose tissue (millimetres); WHR – index (centimetres)

The MANOVA for the total sample indicated a significant effect of class on the combined dependent variables (BMI, FAT, WHR, WHtR) with Wilks' Lambda =0.628; F(12, 894.55)=11.61; p<0.001 (table 2). This suggests that the mean values of these variables differ significantly among the four grades. For the boys' subgroup, the MANOVA results indicated significant differences in the combined measures as well, with Wilks' Lambda =0.605; F(12, 434.19)=7.55; p<0.001. In the girls' subgroup, the MANOVA showed significant effects as well, with Wilks' Lambda =0.615; F(12, 442.12)=7.43; p<0.001. The findings indicate that class has a significant effect on BMI, FAT, and WHR across the total sample, as well as within each gender group. However, WHtR did not demonstrate significant differences.

Table 2. MANOVA Results for the Effect of Class on Morphological Variables

Variable	Total Sample	Boys	Girls
	F=11.61, p=0.00*	**F=7.55, p=0.00***	**F=7.43, p=0.00***
BMI (kg/m^2)	14.12, p=0.000*	7.43, p=0.000*	5.81, p=0.001*
FAT (mm)	5.69, p=0.001*	6.02, p=0.001*	6.54, p=0.000*
WHR (cm)	5.22, p=0.002*	2.46, p=0.065	10.02, p=0.000*
WHtR (cm)	1.61, p=0.186	0.96, p=0.415	2.29, p=0.081

Legend: BMI – body mass index (kilograms/meters^2); FAT – subcutaneous adipose tissue (millimetres); WHR – Waist-to-Hip Ratio (centimetres); WHtR – Waist-to-Height Ratio (centimetres); F – F-value; p – p-value; * – statistically significant differences.

These tests were conducted to identify specific group differences after establishing overall significant effects through MANOVA. Post Hoc for BMI is presented in Table 3.

The Tukey post hoc test for BMI revealed significant differences between classes. The mean BMI values for each class were as follows: Class 1 (15.13 kg/m^2), Class 2 (17.06 kg/m^2), Class 3 (17.54 kg/m^2), and Class 4 (18.16 kg/m^2). The significant differences indicate that Class 1 has a significantly lower BMI compared to Classes 2, 3, and 4. However, there were no significant differences in BMI between Classes 2, 3, and 4, suggesting that once past Class 1, BMI values stabilize across the remaining classes.

Table 3. Post Hoc Comparisons for Body Mass Index (BMI) by Class

Class Comparison	p-value
Class 1 vs. Class 2	0.001*
Class 1 vs. Class 3	0.000*
Class 1 vs. Class 4	0.000*
Class 2 vs. Class 3	0.775
Class 2 vs. Class 4	0.076
Class 3 vs. Class 4	0.556

Legend: p<0.05 indicates a statistically significant difference.

Table 4 shows the analysis for FAT which produced mean values of 19.10 mm (Class 1), 21.05 mm (Class 2), 25.96 mm (Class 3), and 17.70 mm (Class 4). The results indicate significant differences in FAT between Class 1 and Class 3, with Class 3 exhibiting the highest subcutaneous fat levels. Additionally, a significant difference was observed between Class 3 and Class 4, where Class 3 had higher FAT measurements. The lack of significant differences among other class comparisons suggests that FAT levels are notably higher in Class 3 compared to Classes 1 and 4, with Class 2 remaining relatively stable.

For WHR, the mean values were 0.90 (Class 1), 0.88 (Class 2), 0.87 (Class 3), and 0.88 (Class 4) which can be seen in Table 5. The significant findings indicate that Class 1 has a higher WHR compared to Classes 2 and 3. However, there were no

Table 4. Post Hoc Comparisons for Subcutaneous Fat (FAT) by Class

Class Comparison	p-value
Class 1 vs. Class 2	0.813
Class 1 vs. Class 3	0.013*
Class 1 vs. Class 4	0.908
Class 2 vs. Class 3	0.107
Class 2 vs. Class 4	0.337
Class 3 vs. Class 4	0.000*

Legend: p<0.05 indicates a statistically significant difference.

Table 5. Post Hoc Comparisons for Waist-Hip Ratio (WHR) by Class

Class Comparison	p-value
Class 1 vs. Class 2	0.011*
Class 1 vs. Class 3	0.001*
Class 1 vs. Class 4	0.087
Class 2 vs. Class 3	0.879
Class 2 vs. Class 4	0.786
Class 3 vs. Class 4	0.334

Legend: p<0.05 indicates a statistically significant difference.

significant differences between Classes 2, 3, and 4, suggesting that once again, Class 1 distinguishes itself from the others but does not show varying trends among the latter classes.

Overall, the Tukey post hoc analyses reveal distinct patterns among the classes for BMI, FAT, and WHR. Class 1 consistently shows significant differences compared to other classes, particularly in BMI and WHR, while Class 3 stands out in FAT.

Discussion

The results indicate a continuous increase in the values of body mass index, subcutaneous fat and WHR index with an increase in chronological age. In the graphic representation of the distribution of the degree of nutrition, a higher incidence of overweight and obesity is also visible from class to class, in other words, there is an increasing percentage of children with a deviation of the body mass index from the optimal one, but also with the values of the body mass index that are increasingly seriously endangering health. A similar distribution of the level of nutrition of preschool children was obtained by Ljubičić, Mužanović and Petrić (2022), and Pranjić (2023) on the population of children in the year before starting school.

Overweight and obesity are more pronounced among boys (31%), compared to girls (28%) (WHO, 2023), and it has been observed that this trend mostly exists in high-income and upper-middle-income countries (Lobstein & Brinsden, 2019). In this study, there is a significant difference between girls and boys. Girls have lower values of body mass index, subcutaneous fat and WHR index compared to boys. Differences in the prevalence of indicators of overweight and obesity may be partly caused by biological as well as sociocultural influences, but possible conclusions about the reasons and implications of these differences have not yet been concretely confirmed (Shah, Tombeau, Fuller, Birken & Anderson, 2020). It is interesting to note the fact that the average value of the WHR index of girls belongs to abdominal obesity, although they have lower values than boys, even in the remaining two variables. The criteria for abdominal obesity in boys is WHR>0.90, and girls WHR>0.80 (Verma, Rajput, Sahoo, Kaur, & Rohilla, 2016). Therefore, the distribution of subcutaneous fat can play an important role in understanding the overall health profile of children. In other words, BMI is not the only measure that indicates the risk of obesity, biological specifics especially in the period of puberty in girls indicate the need to focus attention on the distribution of subcutaneous fat especially in the abdominal area (Kansra, Lakkunarajah, & Jay, 2021). The accumulation of adipose tissue in the abdominal area in children and adolescents increases the risk of cardio-metabolic diseases (Kelishadi, Mirmoghtadaee, Najafi, & Keikha, 2015). Research indicates that risk factors associated with abdominal obesity in children include genetic predispositions as well as insufficient physical activity, socioeconomic status, poor dietary habits, and the duration and quality of sleep (Jebeile, Kelly, O'Malley, & Baur, 2022).

The results also confirmed that there are significant differences in BMI, PMT and WHR between classes in the overall sample, in boys and girls, which is also visible in the graph showing the distribution of nutritional status. Such results can be partially explained by the definition of growth, which implies an increase in body dimensions, such as an increase in body height, body mass, changes in structure, proportions, body composition and different systems (Mišigoj Duraković, 1999). However, it is crucial to consider additional factors such as eating habits, levels of physical activity, psychosocial and socioeconomic influences, and the family environment. These factors serve as indicators of body composition, including subcutaneous fat, and can significantly impact its increase. (Jebeile, Kelly, O'Malley & Baur, 2022). The results suggest that children are at increasing health risk by increasing their chronological age, i.e. that these factors have an increasingly strong impact on poor lifestyle habits and undesirable body composition (de Almeida, 2024). Although the fact of genetic correlation with human body structure (Silventoinen et al., 2023) and growth (Mišigoj Duraković, 1999) should not be overlooked, it is important to insist on factors that are more susceptible to change. Furthermore, the monitoring of interclass differentiation in the observed variables enables the identification of higher risk groups and the evaluation of the effectiveness of the applied interventions. The significant differences in FAT between Class 1 and Class 3, as well as between Class 3 and Class 4, underscore the importance of monitoring adipose tissue, particularly as children progress through their educational journey. These results align with existing literature (Kansra, Lakkunarajah & Jay, 2021) indicating that body fat accumulation tends to increase during adolescence, which could be exacerbated by lifestyle changes associated with the transition to higher classes. This study is crucial in highlighting the increasing prevalence of overweight and obesity among school-aged children, particularly the distinct patterns observed between boys and girls, and the need to focus on the distribution of subcutaneous fat, especially in the abdominal area, to better assess the health risks associated with these conditions. However, one limitation of the study is its cross-sectional design, which does not allow for the examination of long-term trends in body composition changes. Additionally, factors such as dietary habits, physical activity levels, or family socioeconomic status were not considered, which may influence variations in body mass and fat distribution. Future research should aim for longitudinal studies to track body composition changes over time and include a broader set of variables such as lifestyle factors and genetic predispositions. Investigating the effectiveness of targeted interventions aimed at reducing abdominal fat, especially during puberty, would also provide valuable insights into improving long-term health outcomes.

Conclusion

The research findings indicate that health risk indicators, such as body mass index, subcutaneous fat, waist-to-hip ratio and waist-to-height ratio, become increasingly stable with advancing chronological age in children. This underscores the critical need for public policy adjustments and community-level interventions to facilitate ongoing monitoring of epidemiological trends. A significant difference between girls and boys was also found, with the fact that the body mass index is not a sufficient measure to assess the risk of obesity in girls due to the differentiation in the distribution of subcutaneous fat, which is more pronounced in the abdominal area in girls. This result represents a significant contribution of this research in the form of specific approaches to the prevention of obesity in children of early school age. Due to the insufficient number of facts that would provide an answer to the persistent differentiation in the prevalence of overweight and obesity in childhood, further research is needed to provide more detailed insights into this public health problem. Consequently, this study highlights the importance of a holistic approach to analysing morphological features, which is crucial for better understanding the dynamics of children's growth and development.

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