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Assessment of the relationship between body mass index (BMI) and blood pressure among children aged 9–15 years

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ABSTRACT

Introduction: The increasing prevalence of overweight and obesity among children is a significant public health issue. These conditions are strongly associated with elevated blood pressure, which may lead to primary hypertension already in childhood.

Objective: The objective of this study was to assess the relationship between excessive body weight and the risk of hypertension in children aged 9–15 years.

Material and methods: The study involved a diagnostic survey and blood pressure measurements in a group of children hospitalized in pediatric and nephrology wards. Questionnaire SF-FFQ4PolishChildren questionnaire was used to assess nutritional knowledge and lifestyle.

Results: The findings show a significant correlation between BMI values and elevated systolic and diastolic blood pressure in the study group. Children with overweight or obesity were more likely to exhibit hypertension or prehypertension. Additionally, the general level of knowledge regarding healthy eating and physical activity was low**.**

Conclusions: Overweight and obesity significantly increase the risk of hypertension in children. Early prevention, including education on healthy lifestyles and nutritional habits, is essential.

Key words: children, hypertension, obesity, overweight, BMI, prevention

INTRODUCTION

Overweight and obesity in childhood represent a growing global public health concern, with their prevalence having increased markedly over the past three decades. According to the NCD Risk Factor Collaboration (2024) [1], the global obesity rate among children and adolescents in 2022 was more than four times higher than in 1990, reflecting an alarming epidemiological trend with significant long-term health implications. Excessive body weight in childhood is strongly associated with an increased risk of developing a range of chronic conditions in adulthood, including type 2 diabetes, dyslipidemia, metabolic syndrome, and particularly hypertension [2–4].

The body mass index (BMI), although a relatively simple anthropometric measure, consistently and reliably correlates with blood pressure values in the pediatric population [5,6]. Evidence from large cohort studies shows that elevated BMI in childhood is associated with increased systolic and diastolic blood pressure, even after accounting for age, sex, and height [7,8]. The pathophysiological mechanisms underlying this relationship are multifactorial and include increased sympathetic nervous system activity, activation of the renin–angiotensin–aldosterone system, endothelial dysfunction, and chronic low-grade inflammation [9,10].

In children, hypertension is defined using percentile charts for systolic and diastolic values, adjusted for age, sex, and height, with values above the 95th percentile constituting a diagnosis. Numerous post-2017 studies have shown that the prevalence of hypertension among children with overweight and obesity is significantly higher than among their normal-weight peers. For instance, Xi et al. found that the risk of hypertension was more than three times higher in obese children compared to those with normal BMI [5]. Similarly, Song et al., in a study of over 50,000 school-aged children in China, identified a clear dose–response relationship between BMI z-scores and elevated blood pressure, independent of other lifestyle factors [6].

Lifestyle factors, such as unhealthy eating habits, high consumption of sugar-sweetened beverages, low fruit and vegetable intake, and sedentary behavior, may further exacerbate the relationship between BMI and blood pressure in the pediatric population.

Particularly, low levels of physical activity are recognized both as a direct risk factor for hypertension and indirectly through their impact on body composition.

Given these data, there is an urgent need for studies evaluating the relationship between BMI and blood pressure values in school-aged children to identify modifiable risk factors and develop effective prevention strategies. This study aimed to assess this relationship among children aged 9–15 years, taking into account anthropometric parameters, blood pressure values, dietary habits, and lifestyle, thus contributing valuable insights into cardiovascular risk in the developmental age.

OBJECTIVE

The aim of the conducted study was to assess the impact of excessive body weight on blood pressure values in children aged 9–15 years. An attempt was made to determine the extent to which overweight and obesity may influence the development of hypertension in this age group. The scope of the analysis also included an assessment of lifestyle and the level of knowledge among children regarding healthy eating and physical activity, allowing for a comprehensive evaluation of risk factors contributing to the occurrence of metabolic and hemodynamic disorders in the pediatric population.

MATERIAL AND METHODS

The study was conducted between April and June 2024 among children and adolescents aged 9–15 years who were hospitalized at the Provincial Integrated Hospital in Toruń, in the Clinical Department of Pediatrics and Nephrology, as well as in the Department of Pediatrics, Endocrinology, Diabetology, and Pediatric Neurology. A total of 80 participants with overweight and obesity were enrolled, without the creation of a control group.

Prior to the commencement of the study, written consent was obtained from the Management Board of the Provincial Integrated Hospital in Toruń. Participation in the study was voluntary. Parents/legal guardians of the children were provided with an informed consent form for the child's participation in the study, along with a request to complete a questionnaire. The study was conducted in accordance with the principles of research ethics and the Declaration of Helsinki.

To assess dietary habits, nutritional knowledge, and selected aspects of the children's lifestyle, the standardized and validated research tool SF-FFQ4PolishChildren®,

version 1.1 dated 2 August 2024, was used. This tool was developed by a team of experts from the University of Warmia and Mazury in Olsztyn and the Warsaw University of Life Sciences (authors: J. Kowalkowska, L. Wądołowska, J. Hamułka). The SF-FFQ4PolishChildren® (Short Form Food Frequency Questionnaire for Polish Children) contains questions regarding the frequency of consumption of selected foods and food groups over the past 12 months. Additionally, the tool was used to assess the nutritional knowledge and lifestyle of the study participants.

All children underwent measurements of basic somatic parameters: body weight in kilograms (Radwag C315.100/200.OW-1), height in centimeters (Tanita HR 100 stadiometer), and blood pressure measured three times. Blood pressure was measured using a validated automatic upper-arm sphygmomanometer, with the cuff width individually adjusted according to the child's arm circumference.

Based on anthropometric measurements, the Body Mass Index (BMI) was calculated. Overweight and obesity were assessed using the percentile charts developed by Palczewska I. and Niedźwiecka Z., where BMI values above the 90th percentile indicate overweight, and above the 97th percentile indicate obesity [11].

Blood pressure measurements in children and adolescents were interpreted according to percentile charts for blood pressure, taking into account sex and height. The percentile charts proposed by the OLAF and OLA study research groups were used for this purpose. Normal blood pressure was defined as SBP and DBP < 90th percentile; prehypertension – SBP and DBP between the 90th and 95th percentile; hypertension – SBP and DBP > 95th percentile. Two degrees of hypertension were distinguished: stage 1 HTN – SBP or DBP between the 95th and 99th percentile; stage 2 HTN – SBP or DBP above the 99th percentile. The mean value from the three blood pressure measurements was used in the analyses [12].

Statistical analyses were performed using STATISTICA 13 and IBM SPSS Statistics version 25. The significance level was set at $p = 0.05$. To examine the relationship between excessive body weight and blood pressure values, Pearson's correlation was applied.

RESULTS

In the conducted study involving a group of 80 children aged 9–15 years diagnosed with overweight and obesity, a clear relationship was demonstrated between elevated Body Mass Index (BMI) and blood pressure values. The analysis of the collected data enabled a comprehensive assessment of the children's health status in relation to body weight, blood pressure, and dietary habits.

In terms of body weight assessment, it was found that in the entire study population, 81% of children were obese and 19% were overweight. No case of a child with normal body weight was identified. When broken down by age group, the highest proportion of obesity was found among children aged 12–13 years – as many as 92%. In the 14–15-year age group, obesity affected 81% of children, and in the youngest group aged 9–11 years – 68%. Overweight was most common among younger children (32% in the 9–11-year group), while in older age groups the proportion of overweight children was clearly lower – 8% at ages 12–13 and 19% in the 14–15-year group. Notably, obesity occurred more frequently among girls (87.5%) than boys (75%).

With regard to blood pressure values, the results are also concerning. Only 12.5% of children had normal blood pressure values, and 10% were in the prehypertension range. Stage 1 hypertension was diagnosed in 27.5% of respondents, while as many as 49% met the criteria for stage 2 hypertension. Additionally, in one case (1%), isolated systolic hypertension was diagnosed. Importantly, a higher proportion of stage 2 hypertension was observed among boys (52.5%) compared to girls (45%). Statistical significance testing revealed significant differences in body weight and height parameters between sexes, whereas differences in blood pressure values between boys and girls did not reach statistical significance.

Analysis by age group showed significant differences in body weight, height, and blood pressure between younger children (9–11 years) and those aged 12–13 years. Between the 12–13 and 14–15-year groups, the only statistically significant difference was in height, which may be related to the physiological somatic development during puberty. No significant differences in BMI and blood pressure values were found depending on place of residence (urban vs rural).

Pearson's correlation coefficients confirmed relationships between the analyzed parameters. A moderate correlation was found between BMI and systolic blood pressure ($r = 0.688$), and between BMI and diastolic blood pressure ($r = 0.673$), confirming that an increase

in body weight significantly affects elevated blood pressure values. In addition, a positive correlation was found between body weight and height (r = 0.842), as well as between age and height (r = 0.608) and age and BMI (r = 0.425).

The results of the survey on dietary habits, nutritional knowledge, and lifestyle of children indicate a clearly unsatisfactory level of health-promoting behaviors.

The analysis of the frequency of consumption of selected food products revealed significant deficiencies in meeting dietary recommendations in the studied population of overweight and obese children and adolescents. Only 53% of respondents declared eating breakfast daily, while 19% skipped this meal on most days of the week. Regular consumption of a mid-morning snack, especially on school days, was reported by 61% of participants, with 15% admitting they never ate this meal.

The consumption of vegetables and fruits was below WHO recommendations – 27.5% of respondents ate vegetables daily, and 34% ate fruit daily. A significant proportion (over 40%) consumed vegetables and fruits only a few times a week, and 6% – less than once a week. Whole-grain products were consumed daily by 21% of respondents, while 30% reported eating them less than once a week.

The assessment of consumption of foods high in simple sugars showed that sweets were eaten daily by one-quarter of the study population, and sugary drinks by 19%. Fast food products were consumed by 12.5% of respondents at least 2–3 times per week, and an additional 36% reported eating them once a week. Fish, a source of omega-3 fatty acids, were consumed far too rarely – only 9% of respondents reported eating them twice a week, in accordance with recommendations.

The assessment of nutritional knowledge showed that only 24% of respondents achieved a score classified as high (≥80% correct answers), 46% were in the medium category (50–79% correct answers), and as many as 30% had a low score (<50% correct answers). The highest scores were obtained for questions regarding the identification of food product groups and sources of vitamins and minerals. The largest gaps concerned knowledge of daily intake recommendations for vegetables and fruits, the consequences of excessive salt intake, and the recognition of hidden sources of simple sugars in the diet.

A comparative analysis by sex showed that girls achieved slightly higher scores than boys (by an average of 6 percentage points), although the difference was not statistically significant. In contrast, when broken down by age group, older

children (14–15 years) demonstrated a higher level of knowledge than younger groups, which may be due to longer exposure to health education.

The results concerning physical activity indicate its insufficient level in the studied group. Only 12.5% of participants reported engaging in daily physical activity lasting at least 60 minutes, in line with WHO recommendations, while 39% described their activity level as low (less than 30 minutes per day). The largest proportion of respondents (49%) fell into the category of moderate physical activity (30–59 minutes per day).

Screen time (television, computer, smartphone, console) greatly exceeded recommendations – 36% of respondents spent 2 to 4 hours per day in this way, 29% spent 4 to 6 hours, and 12.5% spent more than 6 hours. The most commonly reported leisure activities were playing computer games and using social media.

In terms of other health-related behaviors, only 41% of respondents slept the recommended 8–10 hours per day, while 23% slept less than 7 hours. Moreover, the analysis of eating habits in the context of lifestyle showed that children with low physical activity more often consumed highly processed products and sugary drinks, and less frequently consumed vegetables, fruits, and whole-grain products.

DISCUSSION

The results of this study clearly confirm a significant relationship between increased body weight and elevated blood pressure values in children aged 9–15 years. The high proportion of children with obesity (81%) and overweight (19%) in the population with diagnosed hypertension or elevated blood pressure is consistent with observations from population studies in other countries [8,13]. In particular, it should be emphasized that in the analyzed group, only 12.5% of children had normal blood pressure values, while almost half met the criteria for stage 2 hypertension. This high percentage is significantly higher than the results reported in large epidemiological analyses, where the prevalence of stage 2 hypertension among obese children ranges between 20–35% [14].

The correlations between BMI and systolic blood pressure ($r = 0.688$) and diastolic blood pressure ($r = 0.673$) reflect a strong metabolic and hemodynamic link

between excessive body weight and blood pressure regulation in the pediatric population. Similar results were obtained by Xi et al. in international reference studies on blood pressure, indicating that BMI is one of the strongest predictors of blood pressure values regardless of age and sex. The mechanisms of this phenomenon include increased sympathetic nervous system activity, insulin resistance, activation of the renin–angiotensin–aldosterone system, and chronic low-grade inflammation [5,13].

The deficiencies in nutritional knowledge and health-promoting behaviors identified in this study constitute an additional factor increasing the risk of hypertension in this group. Only 24% of children achieved a high level of nutritional knowledge, while nearly one-third had a low score. These data are consistent with systematic review findings indicating that a low level of knowledge about healthy eating principles among children and adolescents is associated with higher consumption of highly processed foods and sugary drinks, and lower consumption of vegetables and fruits [15,16].

With regard to physical activity, the obtained results are also concerning. Only 12.5% of respondents met WHO recommendations for at least 60 minutes of moderate or vigorous physical activity daily, while almost 40% reported less than 30 minutes of activity per day. This situation aligns with the global trend of declining physical activity among children and adolescents, particularly in populations with overweight and obesity [16]. Additionally, the high proportion of screen time (more than 4 hours per day in 41.5% of respondents) confirms the observations of Wyszyńska et al., which indicate a significant relationship between a sedentary lifestyle and the risk of obesity and hypertension in children [15].

The results of this study also confirm epidemiological data from Poland, according to which the risk of developing hypertension among overweight adolescents is approximately twice as high, and in the case of obesity – four to five times higher, than in the population with normal body weight [14]. The consistency of these results with literature reports indicates the need for early preventive measures, including health education, dietary interventions, and the promotion of physical activity in the population of children and adolescents with excessive body weight.

CONCLUSION

The obtained results clearly indicate that children with overweight and obesity are at high risk of developing hypertension, and their dietary habits and lifestyle contribute to the persistence of metabolic disorders. The high prevalence of obesity and hypertension in the studied population requires the implementation of effective health prevention strategies, with an emphasis on nutritional education and the promotion of physical activity among both children and their families. The results of this study may serve as an important contribution to the discussion on the necessity of undertaking systemic actions in the prevention of lifestyle-related diseases in the developmental age population.

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