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THE ASSOCIATION BETWEEN BMI WITH HIGH BLOOD PRESSURE IN ADOLESCENTS

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Abstract:

This review explores the association between body mass index (BMI) and high blood pressure in adolescents. The prevalence of high blood pressure in adolescents has been on the rise as well as obesity, and there is a growing body of evidence suggesting a strong correlation between elevated BMI and increased risk of developing high blood pressure. The article reviews various studies and research findings that have investigated this relationship, and discusses potential mechanisms by which elevated BMI may contribute to the development of high blood pressure in adolescents. Additionally, the review highlights the importance of medical intervention and lifestyle modifications to prevent and manage high blood pressure in this population. Overall, the article provides a comprehensive overview of the current understanding of the association between BMI and high blood pressure in adolescents and identifies areas for future research and intervention.

Keywords: *BMI, high blood pressure, hypertension, obesity, overweight*

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INTRODUCTION:

An adequate and balanced diet is essential not only for the survival of people, but also for the enhancement of an entire community. The periods of adolescence and school age are crucial for the acquisition of lifetime habits. An unhealthy dietary habit is observed as one of the perilous behaviors exhibited during this period. Adolescents who have unhealthy diets may experience stunted growth, delayed onset of puberty, iron deficiency anemia, excessive weight gain, being underweight, or obesity. Globally, there has been a rise in the incidence of obesity. The 2010 investigation conducted by the International Obesity Task Force (IOTF) found that there are over 1 billion overweight persons and 475 million obese individuals worldwide. Additionally, there are around 200 million overweight school-age children and 40 to 50 million obese school-age children [1-4].

A study conducted in Turkey involving children aged 6 to 18 has revealed that the prevalence of overweight is 8 to 14%, while the prevalence of obesity is 3 to 31% [5,6]. In recent years, adolescents have been compelled by societal expectations to conform to a specific body size and appearance. However, the primary factors contributing to the rising incidence of obesity, especially among urban adolescents, are the consumption of fast food with poor nutritional value and a decrease in physical activity. The prevalence of obesity among adolescents has become a significant health concern due to reduced levels of physical exercise. Insufficient physical exercise and a sedentary lifestyle are the primary contributors to obesity during both childhood and adolescence [7,8]. As per the Dietary Guidelines established by the World Health Organization (WHO) for Turkey, a significant contributing factor to the rising obesity rates is the prevalent sedentary lifestyle. Consequently, engaging in regular physical exercise is a fundamental element of maintaining a healthy lifestyle [5].

Childhood and adolescent overweight and obesity are significant and escalating worldwide public health issues. Childhood and teenage obesity is linked to several cardiovascular risk factors, including elevated blood pressure (BP), aberrant lipid levels (dyslipidemia), impaired endothelial function, and increased insulin levels (hyperinsulinemia) [9].
Abdominal obesity is also associated with cardiovascular and metabolic risk factors. The comprehensive review included twenty-five longitudinal studies and found that overweight and obese youth, including children and adolescents, had a higher likelihood of developing overweight or obesity in adulthood [10]. Evidence indicates a correlation between childhood overweight and obesity and unfavorable levels of cardiovascular disease risk factors in adulthood. BP throughout childhood is a strong indicator of BP in adulthood [11].

Elevated blood pressure in adulthood is well recognized as a significant factor that heightens the likelihood of developing cardiovascular conditions, including ischemic heart disease, stroke, and hypertensive heart disease. Moreover, it stands as the primary cause of illness and death on a global scale. Hence, it is crucial to initiate the identification of the risk factors linked to the onset of cardiovascular illnesses and other chronic non-communicable diseases. Subsequently, utmost endeavors should be made to avoid and manage these variables during childhood and adolescence [12].

Recent epidemiological studies have indicated a notable rise in the occurrence of high blood pressure in children and adolescents [13,14]. Research has demonstrated a substantial correlation between obesity and hypertension, or high blood pressure (equal to or over the 90th percentile), in children and adolescents. Diverse conclusions have emerged from multiple studies investigating the associations between overweight, obesity, and prehypertension. Insufficient empirical data exists to establish a clear link between abdominal obesity and prehypertension and hypertension in children and adolescents [15-17].
A cross-sectional study was conducted among Lithuanian adolescents (12-15 years) to investigate the correlations among overweight, obesity, abdominal obesity, and prehypertension and hypertension, showed that excess weight, obesity, and fat accumulation in the abdomen were linked to prehypertension and hypertension [12].

A cross-sectional study was held to examine the correlation between hypertension and obesity in Egyptian adolescents revealed that both general obesity and abdominal obesity were important indicators of elevated blood pressure in Egyptian adolescents [18].

Understanding High Blood Pressure in Adolescents:

According to the American Heart Association, systemic hypertension is one of the seven indicators of compromised cardiovascular health [19]. Systemic hypertension (HTN) during childhood and adolescence is a significant risk factor that can predict the development of hypertension and cardiovascular disease (CVD) in adulthood [20].

Hypertension in young individuals is linked to higher left ventricular mass (LVM), increased carotid intima-media thickness (cIMT), less flexible arteries, impaired endothelial function, and negative effects on both kidney function and neurocognitive abilities. There is evidence that high blood pressure in childhood continues throughout adulthood, and hypertension in adulthood is a major cause of illness and death. Therefore, it is essential to employ suitable diagnostic, management, and therapy approaches in youngsters. Nevertheless, the identification of HTN can be complex and sometimes overlooked [21,22].

The prevalence of HBP and HTN among youngsters is mostly determined by analyzing weighted samples from the NHANES [23]. Examinations of more current NHANES (1999–2012) data, along with other studies that look at different groups of people at one point in time and studies that follow people over time, indicate a significant connection between obesity and high blood pressure (HBP) in young people. This means that the occurrence of high blood pressure in children is more common among those who are overweight or obese [24,25]. Children and adolescents who have specific chronic conditions, like chronic kidney disease (CKD), likewise have a higher occurrence of HBP and hypertension. Based on the CKD in Children study, 37% of young individuals with CKD had high systolic blood pressure (SBP) or diastolic blood pressure (DBP) levels above the 90th percentile. Additionally, 14% of them were diagnosed with hypertension, as their SBP and/or DBP values were equal to or greater than the 95th percentile, confirmed through repeated blood pressure assessments [26].

Based on the Fourth Report and previous reports, the diagnosis of hypertension in young individuals is solely determined through statistical analysis of the distribution of blood pressure readings recorded in this age group. Regrettably, the blood pressures utilized for constructing BP percentiles in the Fourth Report were derived from youngsters encompassing both normal and abnormal weight, so distorting the average value. Furthermore, it is worth noting that at the age of 13, the 90th percentile for blood pressure is roughly 120/80 mm Hg. In the past, it was conceivable for young people who transitioned to adult treatment at the age of 18 to have a "normal" blood pressure reading according to pediatric standards but still be classified as having an "abnormal" blood pressure according to adult standards. Consequently, the 2017 Clinical Practice Guidelines (CPG) updated the definition of HTN to align with statistical definitions for children under 13 years old and to adopt adult cutoff values for kids aged 13 and above [27].

Factors Influencing BMI in Adolescents:

Overweight is characterized by a Body Mass Index (BMI) falling between the 85th and 95th percentiles particular to age and sex. Obesity, on the other hand, is characterized by a BMI above the 95th percentile unique to age and sex [2].

Obesity is linked to substantial health hazards and coexisting medical conditions, including cardiovascular disease, hypertension, hyperlipidemia, type 2 diabetes, and specific forms of cancer [28]. It is linked to a higher likelihood of illness and death, as well as a shorter lifespan. Obese males have a life expectancy that is 4.2 years lower than persons of healthy weight, starting from age 40. Similarly, obese women have a life expectancy that is 3.5 years shorter [29]. In 2015, a high Body Mass Index (BMI) was a significant factor in around 4 million deaths worldwide. Multiple studies and meta-analyses have established robust correlations between BMI (Body Mass Index) and almost all causes of mortality, with the notable exclusion of transportation-related accidents. The correlation between mortality and BMI is more pronounced in younger individuals compared to older individuals, and frequently follows a U-shaped pattern with the lowest mortality rates observed in the healthy BMI range. Regrettably, over the past 20 years, there has been a rise in the occurrence of AOO (acute-onset obesity) and its associated health problems, leading to an escalation in healthcare expenses [30-32].

Indonesia is among the nations grappling with the dual challenge of malnutrition, characterized by a rising incidence of overweight and obesity, as well as undernutrition. According to the Indonesian National Health Survey (INHS) 2013, 18.8% of children and adolescents between the ages of 5 and 12 were classified as overweight or obese. Similarly, 10.8% of adolescents aged 13 to 15 years and 7.3% of adolescents aged 16 to 18 years were also overweight or obese. By 2018, the rates of occurrence had risen to 20% for children aged 5 to 12 years, 16% for adolescents aged 13 to 15 years, and 13.5% for teenagers aged 16 to 18 years. If attention and interventions are not addressed, the national prevalence of AOO is projected to double by 2030, following the trend shown in other nations [33].

The cause of AOO is influenced by multiple factors. The presence of genetic, neuroendocrine, metabolic, psychological, environmental, behavioral, and sociocultural elements interacting with each other is apparent [34]. Nevertheless, there has been limited

evaluation of the connections between many factors and the occurrence of obesity in countries facing a range of issues such as overweight and obesity, malnutrition, infectious diseases, and rapid economic and social changes. Gaining a more comprehensive understanding of the frequency of AOO, as well as the factors that contribute to it, is essential for the creation of successful prevention methods. This knowledge will also assist in making informed decisions to maximize the effectiveness and implementation of various policies and strategies [35].

The Association Between BMI and High Blood Pressure:

Several community-based studies have shown a robust positive correlation between BMI and blood pressure in youngsters [36-38]. Through a chain of researches, it has been definitively shown that children with higher BMI or ponderosity percentiles have considerably higher systolic blood pressure compared to their leaner counterparts. Moreover, the ongoing monitoring of children who were part of the initial group showed that those who consistently had high BMI values experienced a much greater increase in systolic blood pressure as time passed compared to those who consistently had low BMI values [39].

Comparisons between obese children referred to pediatric weight reduction clinics and their leaner counterparts have shown that overweight and obese children exhibit considerably elevated blood pressure compared to their lean friends, with a clear relationship between the degree of obesity and blood pressure levels. The correlation between BMI and systolic blood pressure has been replicated in many extensive population-based studies, such as NHANES III. Notably, data from national surveys show a clear pattern of increasing average blood pressure levels in youngsters in the US. The authors of the study explain this tendency to the growing number of overweight young people [36,37].

Although several population-based studies have shown a correlation between body habitus (physical characteristics) and SBP, few papers have specifically addressed the prevalence of high blood pressure (hypertension) in these communities. The lack of clarity in defining high blood pressure in children is justified, given that it is influenced by various factors such as age, relative height, and gender [39].

Two surveys conducted within the community have aimed to overcome this constraint [40,41]. Within a study involving 5100 children aged 10-19 years, Sorof and colleagues found that the occurrence of high blood pressure was more common in children with higher BMI values. Additionally, it was observed that 38% of overweight children (with a BMI above the 95th percentile) exhibited high-normal blood pressure for their height during the initial screening. Additionally, the Quebec Family Study found that a cohort of Canadian adolescents had a comparable prevalence of high-normal systolic blood pressure, at a rate of 30%. Multiple linear regression analysis demonstrated that BMI was a significant predictor of systolic blood pressure (β = 0.9–1.1, $p < 0.001$) among children aged 9, 13, and 16 years. Collectively, this evidence strongly indicates that being overweight is a crucial factor in causing increased systolic blood pressure in children and adolescents, and is a significant contributor to the growing occurrence of high blood pressure in this age group [40].

Pathogenesis of HBP Associated with Increased BMI:

Obesity-induced hypertension is caused by numerous causes that may occur consecutively. The factors involved are: changes in the production of constricting and relaxing factors derived from the endothelium, disruption of molecular signaling, heightened oxidative stress, kidney damage, elevated insulin levels and resistance, sleep apnea syndrome, and the leptin-melanocortin pathway. Cardiovascular and hemodynamic changes vary depending on the pattern of obesity. Individuals with peripheral obesity exhibit increased cardiac output (CO) and decreased systemic vascular resistance (SVR), whereas those with central obesity experience decreased CO and increased SVR [42].

Adipose tissue, at the cellular level, causes endothelial dysfunction by the secretion of several hormones and paracrine signals called adipokines. These molecules have a crucial physiological function in controlling vascular tone. In obesity, there is an overproduction of pro-inflammatory and vasoactive adipokines, such as angiotensinogen, angiotensin II, aldosterone, and resisting. Additionally, there is an elevation in plasma renin activity. Furthermore, there is an upregulation of renin receptor expression in human visceral adipose tissue. Obesity causes structural changes in the endothelium tissue. Such instance is the endothelium glycocalyx layer. Researchers discovered that mice that were only given a diet high in fat exhibited a reduction in thickness and increased rigidity of their glycocalyx. Consequently, this is linked to a notable reduction in the responsiveness of inwardly rectifying potassium (Kir) channels. These channels are

accountable for the phenomenon of vasodilation caused by the movement of fluids [43,44].

In relation to oxidative stress, the excessive metabolism of free fatty acids (FFAs) through β-oxidation and the tricarboxylic acid (TCA) cycle results in an overproduction of reactive oxygen species (ROS). Adipocyte cells experience an increase in ROS production due to the stimulation of NADPH oxidase by FFAs. NADPH oxidase is an enzyme that has a role in generating superoxide radicals, nutrient-based ROS, and causing vascular damage. FFAs, generated by excessive fat accumulation, can induce oxidative stress by indirectly activating NADPH oxidase. This occurs through the stimulation of diacylglycerol synthesis, which in turn activates protein kinase C, a direct activator of NADPH. Activation of NADPH oxidase can potentially contribute to the development of hypertension by activating the central sympathetic system. Obesity-induced hyperlipidemia can exacerbate atherosclerotic vascular injury, leading to hypertension due to the accumulation of tiny VLDL and LDL particles in the inner lining of blood arteries [44-46].

Management Approaches:

The main objective of treating hypertension associated with obesity is to achieve weight loss, as this effectively counteracts the underlying physiological mechanisms that perpetuate high blood pressure. The impact of weight reduction on reducing blood pressure seems to follow a consistent pattern, with a decrease of approximately 1 mmHg per kilogram of weight loss. However, this effect may be less pronounced with time, with a decrease of around 6 mmHg recorded every 10 kilograms of weight loss. The initial strategy for reducing weight involves non-pharmacological methods, mostly focusing on making lifestyle modifications. If individuals are unable to maintain weight loss or achieve the prescribed blood pressure targets using this method, further medication may be necessary. Metabolic surgery is now widely acknowledged as a successful approach to controlling blood pressure in obese patients with hypertension [47].

Adopting changes to lifestyle

Lifestyle modification, which involves restricting caloric intake and increasing physical activity, is the primary approach to treating obesity. Lifestyle therapies encompass food modifications, consistent physical activity, and behavioral alterations. Specific program details are discussed in other sources and are not within the scope of this review. Regrettably, the rates of relapse and discontinuation are elevated, and only a small number of patients manage to attain and sustain long-term weight reduction just with lifestyle improvements. This phenomenon cannot be simply attributed to a decrease in motivation, as it may also be caused by counter-regulatory hormonal processes that aim to restore higher body weight [48,49].

Medications for obesity

As per the recommendations of the ACC/AHA and the Endocrine Society, medications for obesity can be considered as helpful additions to lifestyle changes for patients with a body mass index (BMI) of 30 kg/m2 or higher, or for those with a BMI of 27 kg/m2 or higher who also have obesity-related conditions such as hypertension, type 2 diabetes, dyslipidemia, or obstructive sleep apnea (OSA). At present, the US Food and Drug Administration (FDA) has approved five medications for the purpose of long-term weight management [50]. These pharmaceuticals include orlistat, lorcaserin, phenteramine-topiramate, naltrexone-bupropion, and liraglutide. Except for orlistat, which inhibits gastric and pancreatic lipase to decrease fat absorption, all medications facilitate weight loss by decreasing food consumption and generating a feeling of fullness. Anti-obesity medicines can lead to a weight loss of around 3-9% beyond what can be obtained with lifestyle changes alone when used for over 1 year [51]. While it is not possible to provide an extensive discussion of each medication in this review, it is important to mention that certain anti-obesity treatments may have different impacts on blood pressure. For instance, orlistat has demonstrated a placebo-adjusted decrease in systolic blood pressure of 2.5 mmHg and a decrease in diastolic blood pressure of 1.9 mmHg in obese patients with hypertension. Nevertheless, it is linked to a modest level of weight reduction (less than 3% compared to a placebo) and frequent digestive system adverse effects, such as a sudden need to defecate, lack of bowel control, and greasy stool, which impede its extended usage. Bupropion-naltrexone, when compared to a placebo, results in a weight reduction of roughly 4-5%. However, it can elevate blood pressure and heart rate, and is not advised for usage in individuals with hypertension (84). In general, there is a lack of data regarding the effectiveness and immediate and long-term blood pressure effects of the majority of authorized anti-obesity medications that are specifically targeted at obese patients with hypertension [52,53].

Treatment options for high blood pressure in obese individuals

Obese individuals have a higher likelihood of developing treatment-resistant hypertension, which is characterized by blood pressure that remains above

the desired level after using three different types of antihypertensive drugs simultaneously or having stabilized blood pressure with more than three medications. Although the majority of hypertension guidelines do not specifically focus on obese individuals as a separate group, several suggestions have been made regarding the best selection of antihypertensive medication for this population [54]. Considering the involvement of the Renin-Angiotensin-Aldosterone System (RAAS) in the development of hypertension related to obesity, it is highly recommended to prioritize the use of Angiotensin-Converting Enzyme Inhibitors (ACEIs) and Angiotensin Receptor Blockers (ARBs) as the initial treatment options [55]. These medications offer the additional benefit of enhancing insulin sensitivity and providing kidney protection in people with diabetes, a common coexisting condition in obese adults. Considering the finding that aldosterone levels are increased in obesity, there has been a suggestion to employ MRAs. However, there is limited data to support the idea that these agents are more effective in obese individuals compared to hypertensive patients of normal weight. Given that SNS activation is also involved in hypertension associated to obesity, β-blockers seem to be a scientifically reasonable choice for treatment. Nevertheless, a considerable number of medications in this category are linked to an increase in body weight and a decrease in insulin sensitivity [56]. Therefore, their usage should be restricted to overweight individuals who have particular cardiovascular conditions, such as heart failure or post-myocardial infarction. When β-blockers are recommended, third generation medicines like carvedilol and nebivolol seem to have a lower likelihood of causing weight gain and fewer negative effects on metabolism compared to previous β-blockers. Dihydropyridine calcium channel blockers have a neutral impact on glucose metabolism and weight gain. They are typically suggested as secondary treatment options in conjunction with ACEIs/ARBs. Thiazide diuretics are effective in reducing the excessive fluid volume associated with hypertension caused by obesity. However, obese people who are treated with these medicines are particularly susceptible to experiencing metabolic side effects such as dyslipidemia and insulin resistance [57].

Treatment options for obesity in children are restricted in terms of pharmacology and surgery. ACE inhibitors and calcium channel blockers are the predominant pharmacological treatments for primary hypertension in children and adolescents [58].

CONCLUSION:

In conclusion, the association between BMI in adolescents and high blood pressure is a significant and concerning issue. The research has shown that there is a clear correlation between higher BMI and an increased risk of developing high blood pressure in adolescents. This highlights the importance of addressing and managing obesity in this age group to prevent the onset of hypertension and its associated health complications. It is crucial for healthcare professionals, parents, and educators to work together to promote healthy lifestyle choices and encourage regular physical activity and a balanced diet to reduce the risk of high blood pressure in adolescents. Further research and intervention strategies are needed to effectively address this public health concern and improve the overall well-being of adolescents.

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