Association Of Body Mass Index With Hypertension Amongst School-Aged Children

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Abstract

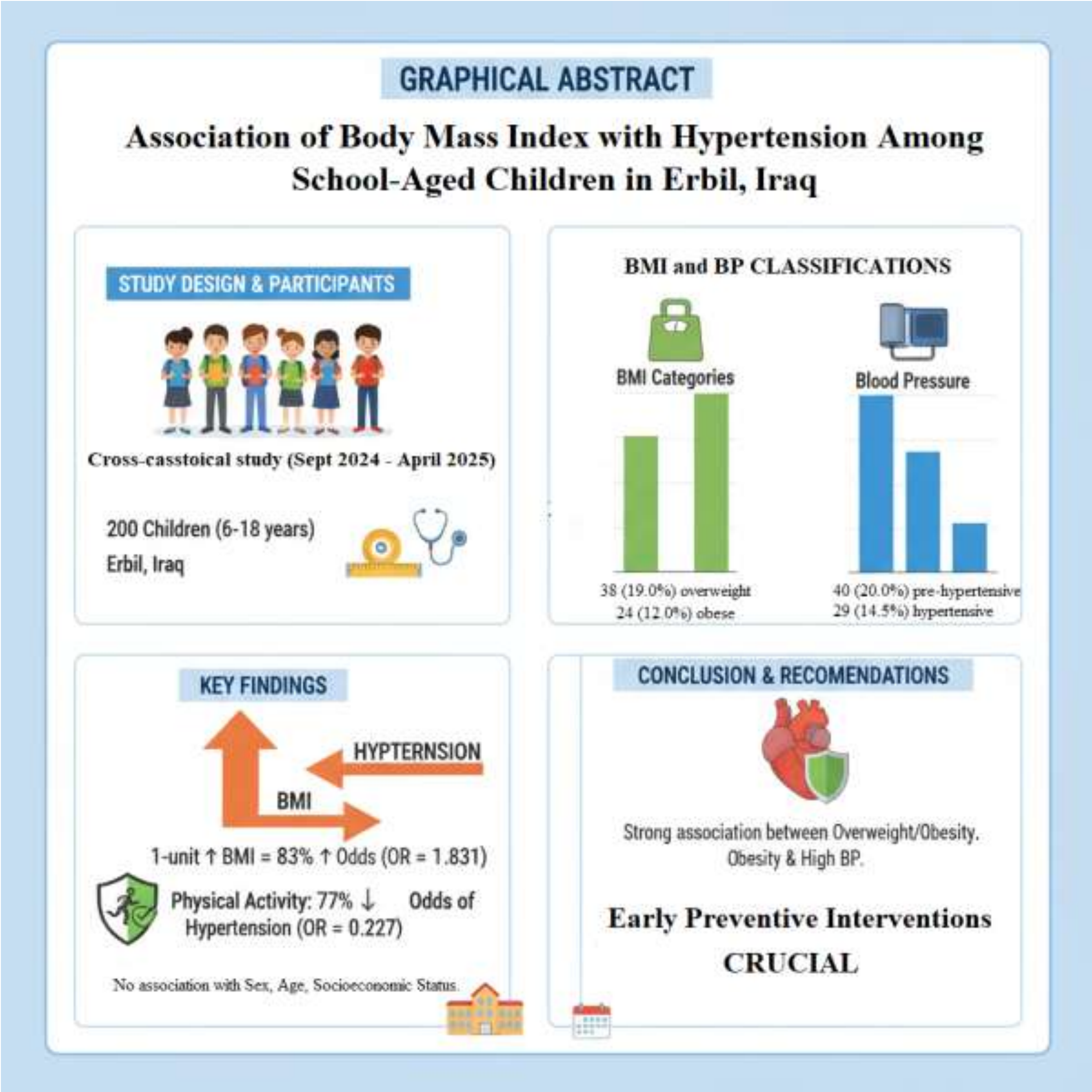
Background and Objectives: Childhood obesity and hypertension (HTN) are emerging public health challenges that predispose to early cardiovascular disease. This study aimed to determine the prevalence of HTN and its association with body mass index (BMI) categories among school-aged children in Erbil, Iraq, and to assess related demographic and lifestyle risk factors.

Methods: A school-based cross-sectional survey was conducted from September 2024 to April 2025 among 200 children aged 6–18 years, selected through multistage cluster sampling. Anthropometric data were collected per WHO protocols, and blood pressure (BP) was measured using validated pediatric guidelines. HTN was defined as systolic and/or diastolic BP ≥95th percentile for age, sex, and height.

Results: Of the participants, 106 (53.0%) were male, and the mean age was 11.97 ± 3.76 years. Based on BMI classification, 6 (3.0%) were underweight, 132 (66.0%) normal, 38 (19.0%) overweight, and 24 (12.0%) obese. Blood pressure profiles showed 131 (65.5%) normal, 40 (20.0%) pre-hypertensive, and 29 (14.5%) hypertensive children. HTN was strongly associated with obesity, affecting 17 (70.8%) of obese children compared to 3 (2.3%) of normal-weight children ($p < 0.01$). Logistic regression showed that each unit increase in BMI raised the odds of HTN by 83% (OR = 1.831, 95% CI: 1.434–2.339). Physical activity was protective, with highly active children showing only 1 (1.7%) hypertensive case compared to 18 (52.9%) in low activity, corresponding to 77% lower odds (OR = 0.227, 95% CI: 0.092–0.560). No significant associations were found with sex, age, or socioeconomic status.

Conclusion: Childhood overweight and obesity are significantly associated with elevated BP in Erbil. Promoting physical activity and early preventive interventions are crucial to mitigating the growing burden of pediatric HTN in the region.

Graphical Abstract



1. Introduction

Cardiovascular disease (CVD) is a leading cause of mortality globally, with hypertension (HTN) being a significant risk factor for CVD (1). Recent systematic reviews and meta-analyses indicate that approximately 4% of children globally suffer from confirmed HTN, with prevalence rates varying considerably across different regions and populations (2). This alarming trend has been paralleled by the concurrent rise in childhood obesity, creating a complex interplay between elevated body mass index (BMI) and blood pressure (BP) abnormalities in the pediatric population (3).

The BMI-HTN relationship in children follows pathophysiological mechanisms that involve insulin resistance, overactivity of the sympathetic nervous system, sodium retention, and vascular dysfunction. While initially described in adults, researchers are becoming more aware that these mechanisms operate in children and likely contribute to premature cardiovascular complications and the emergence of metabolic syndrome (4). The clinical implications extend beyond childhood, as there is striking tracking of childhood HTN into adulthood, resulting in a dramatic increase in the risk of cardiovascular disease, stroke, and premature death (3).

Observational studies and those employing a Mendelian randomization approach demonstrate that childhood overweight (5), adolescent overweight (6), or significant changes in BMI throughout puberty

(7) correlate with heightened cardiovascular risk in adulthood. One observational study indicated that a high BMI throughout development correlated with elevated BP in later life (8), but another observational study revealed no correlation between BMI assessed during puberty and BP in young adulthood (9). A study conducted in the UK utilizing the Avon Longitudinal Study of Parents and Children (ALSPAC) cohort identified cardiovascular changes indicative of early pathological alterations that could result in arterial stiffness, HTN, and ultimately atherosclerosis in children with a high BMI, whereas no such changes were observed in those with normal weight (10).

Although the current world trends of increasing prevalence of childhood obesity and HTN are strongly supported by well-documented facts, there is still a significant body of knowledge gap in relation to the particular prevalence and phenotypic profiles of HTN related to body-mass-index in school-aged children in Middle East region, and specifically in the country of Iraq. The lack of such region-specific data, in turn, hinders the development of specific prevention programs and evidence-based health policy with respect to this at-risk group. The main aim of the current study was to define the prevalence of HTN and explain its relationship with categorical body-mass-index among school-aged children living in Erbil, Iraq and at the same time, determine the demographic and anthropometric risk factors.

2. Methods and Materials

2.1. Study design and setting

This study was conducted as a school-based cross-sectional survey to assess the association between BMI categories and HTN among school-aged children in Erbil, Iraq. The data collection was conducted over eight months, from September 2024 to April 2025.

2.2. Participants

The study population comprised children aged 6-18 years enrolled in selected primary and secondary schools in Erbil, Iraq. Participants were recruited through collaboration with the Directorate of Education in Erbil, Iraq, which granted official permission for school visits. Within each school, students were selected randomly from class registers. A multistage cluster sampling strategy was employed, first by choosing schools and then by randomly selecting classrooms and students to participate. Prior to inclusion, informed consent was obtained from parents or guardians, and verbal assent was collected from each child.

Children were eligible for participation if they were within the age range of 6-18 years, enrolled in the selected schools, and free from any diagnosed chronic disease that might affect growth, cardiovascular status, or BP regulation. Children with known congenital heart disease, renal disorders, endocrine abnormalities, or those under antihypertensive medication were excluded. Additionally, children who were acutely ill during data collection or who refused to participate were also excluded. This ensured accurate assessment of BMI and BP without significant confounding clinical conditions.

The sample size was determined using the single population proportion formula, considering a 6% prevalence of pediatric HTN reported in previous regional studies (11), a 95% confidence level, and 5% margin of error. Using the formula:

$$n = \frac{Z^2 \,.\, P(1-P)}{d^2}$$

where Z=1.96, P=05, and d=0.05, the calculated minimum sample size was 87. Given the cluster sampling method and potential intra-class correlation, a design effect of 2 was applied. To increase statistical power and account for non-response (10%), the final target sample size was set at 200 participants.

2.3. Data Collection

Data were collected through structured field visits conducted in schools during morning hours (08:00–11:00 AM) to minimize diurnal variation in BP. Teams of trained researchers, consisting of public health specialists and nursing graduates, performed anthropometric and BP measurements following standardized WHO protocols.

2.3.1. Anthropometry

Height was measured using a portable stadiometer (Seca 213, Hamburg, Germany) to the nearest 0.1 cm, with the participant standing barefoot, heels together, head positioned in the Frankfurt plane.

Weight was measured using a calibrated digital scale (Omron HN-286, Kyoto, Japan) to the nearest 0.1 kg, with children wearing light clothing.

BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2). Age- and sex-specific BMI percentiles were classified according to CDC growth charts: underweight (<5th percentile), normal weight (5th–84th percentile), overweight (85th–94th percentile), and obese (≥95th percentile).

2.3.2. Blood Pressure Measurement

Blood pressure was measured using an automated oscillometric sphygmomanometer (Omron HEM-907 XL, Kyoto, Japan), validated for pediatric populations. Appropriate cuff sizes were selected according to mid-arm circumference. Each child was seated comfortably for at least five minutes, with the right arm supported at heart level. Three readings were taken at 2-minute intervals, and the mean of the last two readings was recorded. HTN was defined based on the 2017 American Academy of Pediatrics guidelines, with systolic and/or diastolic BP ≥95th percentile for age, sex, and height. Pre-HTN was defined as readings ≥90th percentile but <95th percentile.

2.3.3. Demographic Information

Parents completed structured questionnaires regarding sociodemographic characteristics, family history of HTN, physical activity, and dietary patterns.

2.4. Ethical Considerations

The protocol received approval from the research ethics committee of ministry of health. Written informed consent was obtained from parents or guardians prior to undertaking the research in accordance with regulatory and ethical standards. Participation was voluntary and participants were free to withdraw at any time without compromising care. Confidentiality was maintained through coded identifiers and data access was restricted. The study adhered to the Declaration of Helsinki (2013) and applicable local regulations.

2.5. Statistical Analysis

Data were entered and analyzed using IBM SPSS Statistics version 26. Descriptive statistics, including means, standard deviations, and proportions, were calculated for demographic and anthropometric variables. Chi-square tests were used to compare categorical variables (e.g., BMI categories vs. BP categories). Logistic regression analysis was performed to assess the association between HTN and other variables. A p-value <0.05 was considered statistically significant.

3. Results

Table 1 presents the demographic characteristics of the 200 school-aged participants in the study. The sample included 106 males (53.0%) and 94 females (47.0%), with a mean age of 11.97 ± 3.76 years. By school level, 112 children (56.0%) were in primary school (ages 6–12), 37 (18.5%) in middle school (ages 13–15), and 51 (25.5%) in high school (ages 16–18). Regarding school distribution, 53 participants (26.5%) were from School 1, 71 (35.5%) from School 2, 54 (27.0%) from School 3, and 22 (11.0%) from School 4. Socioeconomic status varied, with 96 children (48.0%) from low-income families, 78 (39.0%) from middle-income households, and 26 (13.0%) from high-income families.

Table 1. Demographic characteristics of participants.

Variables		Frequency	Percent
Sex	Male	106	53.0
	Female	94	47.0
Age	Mean ± SD	11.97 ± 3.76	
	Primary School (Elementary) (6-12)	112	56.0
	Secondary School (Middle School) (13-15)	37	18.5

	Secondary School (High School) (16-18)	51	25.5
School	1	53	26.5
	2	71	35.5
	3	54	27.0
	4	22	11.0
Socioeconomic Status	Low (Family income <500,000 IQD/month)	96	48.0
	Middle (Family income 500,000-1,500,000 IQD/month)	78	39.0
	High (Family income >1,500,000 IQD/month)	26	13.0

Family HTN History examination showed that 71 (35.5%) participants had no history, while 129 participants (64.5%) had a history (Figure 1).

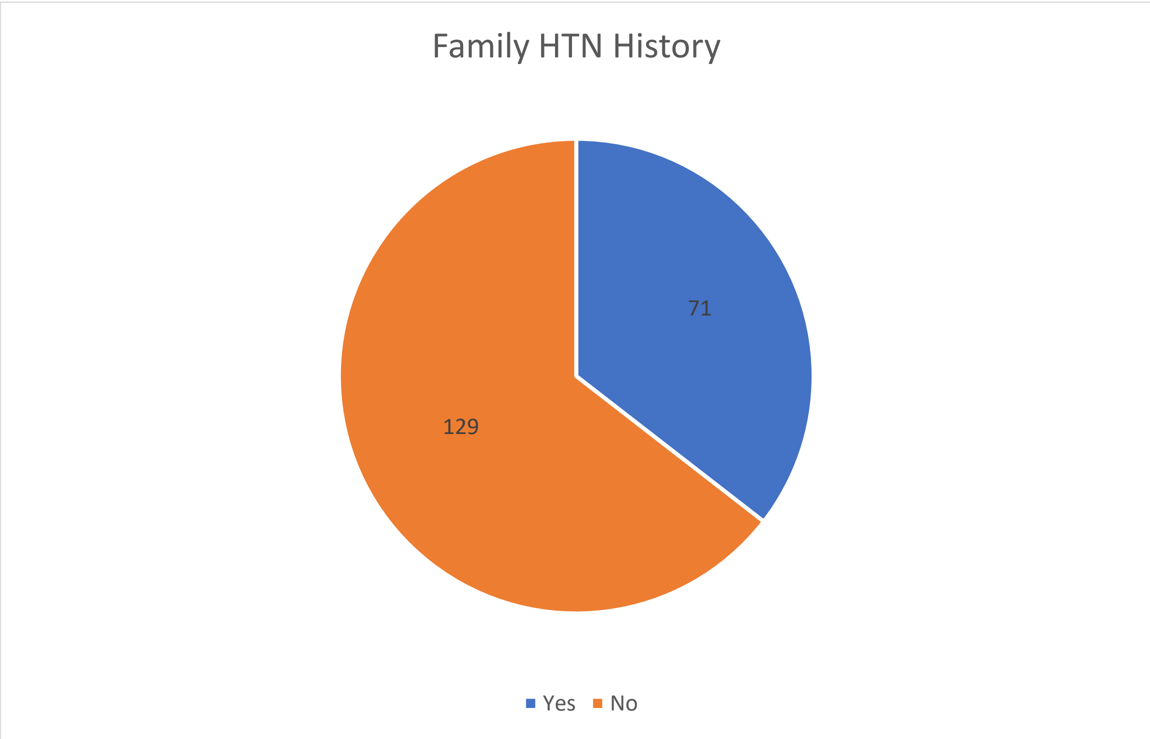


Figure 1. Family HTN History.

Table 2 summarizes the anthropometric characteristics of the participants. The mean height was 135.33 cm with a standard deviation of 20.56 cm, while the mean weight was 37.48 kg with a standard deviation of 14.68 kg. The mean BMI of the participants was 19.74, with a standard deviation of 3.25.

Table 2. Anthropometric measurements of participants.

Variables	Mean	SD
Height	135.33	20.56
Weight	37.48	14.68
BMI	19.74	3.25

Figure 2 shows the classification of participants based on BMI percentiles. The majority of children, 132 (66.0%), fell within the normal BMI range (5th–84th percentile). A smaller proportion, 6 participants (3.0%), were classified as underweight (<5th percentile). Meanwhile, 38 children (19.0%) were overweight (85th–94th percentile), and 24 (12.0%) were obese (≥95th percentile).

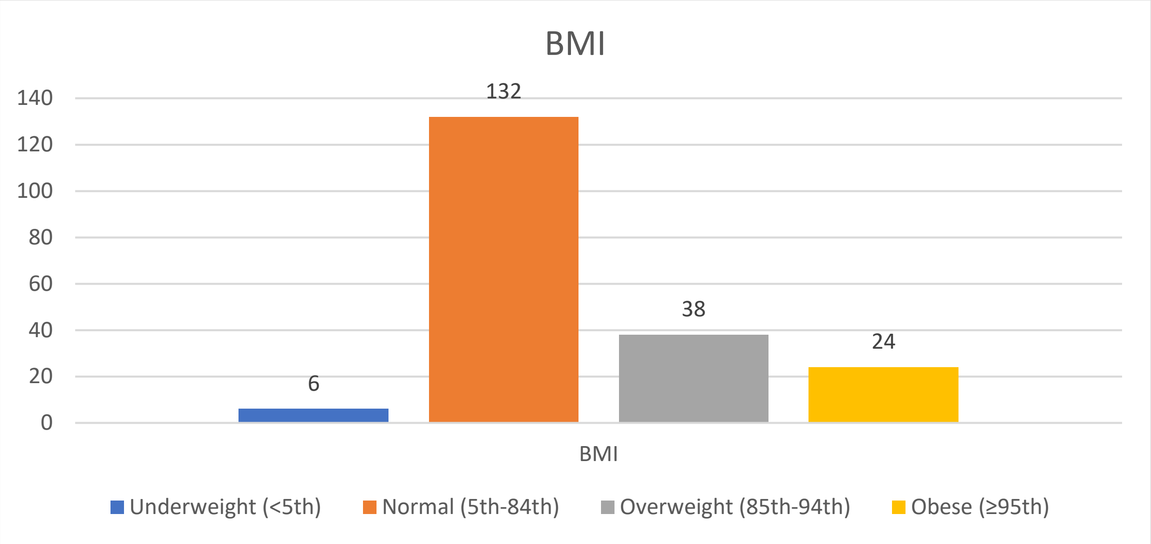


Figure 2. Distribution of participants according to BMI categories.

Table 3 presents the BP profiles of the study participants. The mean systolic BP (SBP) was 114.42 ± 8.46 mmHg, while the mean diastolic blood pressure (DBP) was 73.69 ± 35.90 mmHg. Based on percentile classification, 131 children (65.5%) had normal BP (<90th percentile), 40 (20.0%) were in the pre-HTN range (90th–<95th percentile), and 29 (14.5%) were classified as hypertensive (≥95th percentile).

Table 3. Blood pressure measurements and distribution among participants.

Variables		Frequency	Percent
SBP	Mean ± SD	114.42 ± 8.46	
DBP	Mean ± SD	73.69 ± 35.90	
	Normal (<90th)	131	65.5
BP	Pre-HTN (90th-<95th)	65	20.0
	HTN (≥95th)	29	14.5

Figure 3 describes the physical activity patterns of the participants based on weekly moderate activity. Among the 200 children surveyed, the majority, 107 (53.5%), engaged in moderate levels of activity (150–300 minutes per week). High levels of activity (>300 minutes per week) were reported by 59 participants (29.5%), while only 34 children (17.0%) fell into the low activity group (<150 minutes per week).

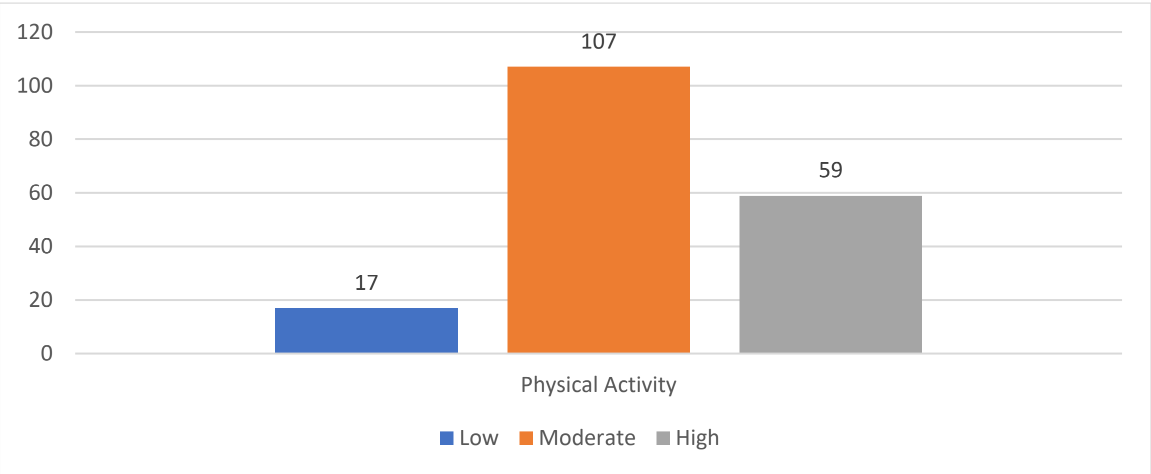


Figure 3. Distribution of participants according to physical activity levels.

Overall, no significant associations were found between BP and sex (p = 0.401), age group (p = 0.093), or socioeconomic status (p = 0.86). However, statistically significant associations were identified for both physical activity (p < 0.01) and BMI (p < 0.01). Children with low physical activity (<150 minutes/week) had the highest burden of HTN, with 18 (52.9%) hypertensive, 8 (23.5%) pre-hypertensive, and only 8 (23.5%) normal, whereas in the high activity group (>300 minutes/week), just 1 (1.7%) was hypertensive and the majority, 46 (78.0%), had normal BP. Similarly, BMI showed strong associations: among obese children, 17 (70.8%) were hypertensive, 5 (20.8%) pre-hypertensive, and only 2 (8.3%) normal; in overweight children, 9 (23.7%) were hypertensive, 17 (44.7%) pre-hypertensive, and 12 (31.6%) normal; while in normal-weight children, HTN was rare with only 3 cases (2.3%) compared to 111 (84.1%) normal and 18 (13.6%) pre-hypertensive. All underweight children, 6 (100.0%), had normal BP (Table 4).

Table 4. Association of demographic, socioeconomic, lifestyle, and BMI factors with BP status among participants.

Variables		BP			P-value
		Normal (<90th)	Pre-HTN (90th-<95th)	HTN (≥95th)	
Sex	Male	66 (62.3%)	25 (23.6%)	15 (14.2%)	0.401
	Female	65 (69.1%)	15 (16.0%)	14 (14.9%)	
	Total	131 (65.5%)	40 (20.0%)	29 (14.5%)	
Age	Primary School	82 (73.2%)	17 (15.2%)	13 (11.6%)	0.093
	Secondary School	23 (62.2%)	8 (21.6%)	6 (16.2%)	
	Secondary School	26 (51.0%)	15 (29.4%)	10 (19.6%)	
	Total	131 (65.5%)	40 (20.0%)	29 (14.5%)	
Socioeconomic Status	Low	58 (60.4%)	27 (28.1%)	11 (11.5%)	0.86
	Middle	54 (69.2%)	10 (12.8%)	14 (17.9%)	
	High	19 (73.1%)	3 (11.5%)	4 (15.4%)	
	Total	131 (65.5%)	40 (20.0%)	29 (14.5%)	
Physical Activity	Low	8 (23.5%)	8 (23.5%)	18 (52.9%)	<0.01
	Moderate	77 (72.0%)	20 (18.7%)	10 (9.3%)	
	High	46 (78.0%)	12 (20.3%)	1 (1.7%)	
	Total	131 (65.5%)	40 (20.0%)	29 (14.5%)	
BMI	Underweight (<5th)	6 (100.0%)	0 (0.0%)	0 (0.0%)	<0.01
	Normal (5th-84th)	111 (84.1%)	18 (13.6%)	3 (2.3%)	
	Overweight (85th-94th)	12 (31.6%)	17 (44.7%)	9 (23.7%)	
	Obese (≥95th)	2 (8.3%)	5 (20.8%)	17 (70.8%)	
	Total	131 (65.5%)	40 (20.0%)	29 (14.5)	

Table 5 presents the results of a logistic regression analysis examining predictors of elevated BP. Both BMI and physical activity emerged as significant factors. Higher BMI was strongly associated with increased odds of elevated BP (B = 0.605, p < 0.001), with an odds ratio (Exp(B)) of 1.831 (95% CI: 1.434–2.339), indicating that for each unit increase in BMI, the likelihood of having elevated BP increased by approximately 83%. In contrast, higher levels of physical activity were protective (B = -

1.484, p = 0.001), with an odds ratio of 0.227 (95% CI: 0.092–0.560), suggesting that physically active children had about 77% lower odds of elevated BP compared to their less active peers.

Table 5. Logistic regression analysis of factors associated with BP among participants.

Variables in the Equation (BP)								
	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
							Lower	Upper
BMI	.605	.125	23.505	1	.000	1.831	1.434	2.339
Physical Activity	-1.484	.461	10.360	1	.001	.227	.092	.560

4. Discussion

Childhood obesity is emerging as a global epidemic with serious repercussions for cardiovascular health, and its prevalence has increased rapidly in both developed and developing countries (12). Understanding the complex interaction of excess body weight and increased BP in children has emerged as a critical public health issue that warrants immediate attention (3). The current study examined the association of BMI and HTN in 200 school-aged children from Erbil, Iraq. Approximately one-third of children were classified as either overweight or obese, 14.5% were identified as hypertensive, and an additional 20% were classified as pre-hypertensive, indicating the significant burden of elevated BP among school-aged children.

The prevalence of HTN observed in this study (14.5%) aligns closely with recent global estimates and regional findings from similar populations. A study by Twig et al. (2019) reported a global childhood HTN prevalence ranging from 4.32% to 7.89%, with peaks occurring around 14 years of age (6). However, studies from developing countries and Middle Eastern regions have consistently reported higher rates, with some investigations documenting prevalence rates exceeding 15% (13). The elevated HTN prevalence in the current study may be attributed to the high proportion of overweight and obese children (31% combined), which is consistent with findings from other studies in the Kurdistan Region of Iraq where childhood obesity rates have been steadily increasing (14). A recent study by Abuzaid et al. (2022) in nearby Erbil reported similar obesity prevalence rates among school children, suggesting a regional trend in the Kurdistan area of Iraq (15).

The substantial relationship between BMI categories and BP status identified by this study supports the considerable international evidence correlating childhood obesity with HTN risk (16). In this study, 70.8% of children with obesity had an elevated risk for HTN compared with 2.3% of the children who were normal weight, yielding a remarkable difference in the prevalence of HTN by BMI categories. This prevalence rate is indeed remarkable similar to findings reported in recent work by Wang et al. (2022), who identified an odds ratio of 3.089 for HTN for children classified as obese compared to a reference group of children classified as normal weight. Furthermore, Wang et al. similarly demonstrated that overweight children had 1.62 increased odds for HTN (17). The outcomes of the present study's logistic regressions are extremely close to the international literature which further validates the BMI-HTN association among children.

The protective effect of physical activity observed in this investigation provides compelling evidence for lifestyle-based interventions in pediatric HTN prevention. Children engaging in high levels of physical activity (>300 minutes per week) demonstrated markedly lower HTN rates (1.7%) compared to those with low activity levels (52.9%). This inverse relationship between physical activity and BP is strongly supported by recent research from Mendes et al. (2024), who reported that Portuguese children with insufficient moderate-to-vigorous physical activity showed 1.63 times higher risk of elevated BP (18). The protective odds ratio of 0.227 for physically active children in the current study aligns with meta-analytical evidence from school-based physical activity interventions, which have consistently demonstrated significant reductions in systolic BP among overweight and obese children (19). These findings support current pediatric guidelines recommending at least 60 minutes of daily physical activity for optimal cardiovascular health (20).

It is worth noting that the presence of no major correlations between HTN and conventional demographic variables including sex, age group, or socioeconomic status in this case is in opposition to a number of global findings. Studies in the developed nations have often reported socioeconomic differences in the rate of childhood obesity and high BP. On the other hand, other studies carried out in similar developing country settings have documented these results to be similar to the current study where lifestyle-associated factors, especially the BMI, and the degree of physical exercise seem to dominate over the sociodemographic factors. This trend could be indicative of the relative homogeneity of the socioeconomic state of the study population or indicate that in the environment with a low level of healthcare access, behavioral risk factors could play a dominant role in the pathogenesis of HTN regardless of family income or education level (13).

Limitations and Future Studies

The current study was limited to a cross-sectional design, hence it did not allow a causal conclusion about the correlation between BMI and the relationship between physical activity and HTN. In addition, the sample included only one governorate, which can reduce the applicability of the results to the other parts of the Iraqi terrain, or the Middle East, in general. Recall bias also is at risk because of self-reported data on physical activity as well as family history. Bigger and more heterogeneous cohorts in future longitudinal studies are required to improve our understanding of causal paths and HTN trends during adulthood. Also, biochemical markers e.g. lipid profiles, insulin resistance indices, and inflammatory markers may provide a better insight into the metabolic processes underlying HTN in obese children, whereas intervention-oriented studies may be exploring the effectiveness of more specific public health interventions in reversing these patterns.

5. Conclusions

The current study defined a statistically significant relationship between high BMI and HTN among school-aged children living in Erbil, Iraq. The prevalence of elevated BP was significantly higher in overweight and obese participants compared to normally weight children. One third of the sample was found to be overweight or obese with a similar percentage showing either pre-HTN or HTN, thus highlighting an urgent health need in society. Furthermore, physical activity emerged as a strong protective factor, with children engaging in higher levels of weekly activity showing substantially lower odds of developing HTN. These findings support the critical role of the timely identification of at-risk children, promotion of healthful lifestyle habits, and development of school- and community-based programs, in particular, aimed at mitigating childhood obesity and HTN in the area.

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Conflict of interest: All authors declare no conflict of interest.

Data availability: The study data may be acquired from the relevant author upon a reasonable request.

Authors' contributions: Each author made an equal contribution to this research work.

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References

1. Yusuf S, Joseph P, Rangarajan S, Islam S, Mente A, Hystad P, et al. Modifiable risk factors, cardiovascular disease, and mortality in 155 722 individuals from 21 high-income, middle-income, and low-income countries (PURE): a prospective cohort study. Lancet (London, England). 2020;395(10226):795-808. https://doi.org/10.1016/s0140-6736(19)32008-2
2. Song P, Zhang Y, Yu J, Zha M, Zhu Y, Rahimi K, et al. Global Prevalence of Hypertension in Children: A Systematic Review and Meta-analysis. JAMA pediatrics. 2019;173(12):1154-63. https://doi.org/10.1001/jamapediatrics.2019.3310
3. Jeong SI, Kim SH. Obesity and hypertension in children and adolescents. Clinical hypertension. 2024;30(1):23. https://doi.org/10.1186/s40885-024-00278-5

4. Wójcik M, Alvarez-Pitti J, Kozioł-Kozakowska A, Brzeziński M, Gabbianelli R, Herceg-Čavrak V, et al. Psychosocial and environmental risk factors of obesity and hypertension in children and adolescents—a literature overview. Frontiers in cardiovascular medicine. 2023;10:1268364.
5. Richardson TG, Sanderson E, Elsworth B, Tilling K, Davey Smith G. Use of genetic variation to separate the effects of early and later life adiposity on disease risk: mendelian randomisation study. BMJ (Clinical research ed). 2020;369:m1203. https://doi.org/10.1136/bmj.m1203
6. Twig G, Yaniv G, Levine H, Leiba A, Goldberger N, Derazne E, et al. Body-Mass Index in 2.3 Million Adolescents and Cardiovascular Death in Adulthood. The New England journal of medicine. 2016;374(25):2430-40. https://doi.org/10.1056/nejmoa1503840
7. Kindblom JM, Bygdell M, Hjelmgren O, Martikainen J, Rosengren A, Bergström G, et al. Pubertal Body Mass Index Change Is Associated With Adult Coronary Atherosclerosis and Acute Coronary Events in Men. Arteriosclerosis, thrombosis, and vascular biology. 2021;41(8):2318-27. https://doi.org/10.1161/atvbaha.121.316265
8. Sabo RT, Lu Z, Daniels S, Sun SS. Serial childhood BMI and associations with adult hypertension and obesity: the Fels Longitudinal Study. Obesity (Silver Spring, Md). 2012;20(8):1741-3. https://doi.org/10.1038/oby.2012.58
9. Rademacher ER, Jacobs DR, Jr., Moran A, Steinberger J, Prineas RJ, Sinaiko A. Relation of blood pressure and body mass index during childhood to cardiovascular risk factor levels in young adults. Journal of hypertension. 2009;27(9):1766-74. https://doi.org/10.1097/hjh.0b013e32832e8cfa
10. Dangardt F, Charakida M, Georgiopoulos G, Chiesa ST, Rapala A, Wade KH, et al. Association between fat mass through adolescence and arterial stiffness: a population-based study from The Avon Longitudinal Study of Parents and Children. The Lancet Child & adolescent health. 2019;3(7):474-81. 10.1016/s2352-4642(19)30105-1
11. Majeed A, Haleem A. Prevalence of hypertension and its associated risk factors among secondary school students in Duhok City. Healthcare in Low-resource Settings. 2024;1(1):1. http://dx.doi.org/10.4081/hls.2024.12073
12. Kerr J. Global, regional, and national prevalence of child and adolescent overweight and obesity, 1990-2021, with forecasts to 2050: a forecasting study for the Global Burden of Disease Study 2021. Lancet (London, England). 2025;405(10481):785-812. https://doi.org/10.1016/S0140-6736(25)00397-6s
13. Obita G, Alkhatib A. Disparities in the Prevalence of Childhood Obesity-Related Comorbidities: A Systematic Review. Frontiers in public health. 2022;10:923744. https://doi.org/10.3389/fpubh.2022.923744
14. Salih KKH, Ali SJ, Ahmed AMA. Prevalence of Obesity among Students in Private and Public high Schools in Sulaimani City. Diyala Journal of Medicine. 2023;24(2):24-34. https://djm.uodiyala.edu.iq/index.php/djm/article/view/994/version/967
15. Abuzaid MM, Elshami W, Fadden SM. Integration of artificial intelligence into nursing practice. Health and Technology. 2022;12(6):1109-15.
16. Wang L, Ren L, Wang Y, Ji Z, Zhu R, Sun Y, et al. Effect of body mass index trajectory on hypertension among children and adolescents aged 5-18 years: a retrospective cohort study. Annals of medicine. 2023;55(2):2267572. https://doi.org/10.1080/07853890.2023.2267572
17. Wang Y, Min C, Song X, Zhang H, Yuan C, Chen L, et al. The dose-response relationship between BMI and hypertension based on restricted cubic spline functions in children and adolescents: A cross-sectional study. Frontiers in public health. 2022;10:870568. https://doi.org/10.3389/fpubh.2022.870568
18. Mendes E, Farinatti P, Andaki A, Santos APD, Cordeiro J, Vale S, et al. Relationship Among Body Mass Index, Physical Activity, Sedentary Behavior, and Blood Pressure in Portuguese Children and Adolescents: A Cross-Sectional Study. International journal of environmental research and public health. 2024;22(1):20. https://doi.org/10.3390/ijerph22010020
19. Mao D, Li B. Evaluating the Role of School-Based Physical Activity in Mitigating Cardiometabolic Risk Factors in Children and Adolescents with Overweight or Obesity: A Systematic Review and Meta-Analysis. Children. 2025;12(4):439. https://doi.org/10.3390/children12040439

20. Almonacid-Fierro A, González-Almonacid J. The pandemic of childhood obesity: Challenges and possibilities from physical activity. Health Promotion Perspectives. 2022;12(3):229. https://doi.org/10.34172/hpp.2022.29