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Original Research Article

Body Mass Index (BMI) Associations with Hypertension and Cardiovascular Risks in School-Going Children

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Abstract:

Aim: This systematic review evaluates the association between body mass index (BMI) and cardiovascular risk profiles in school-going children. The central objective is to synthesize evidence on whether increasing adiposity, commonly operationalized through BMI categories or BMI z-scores, is associated with elevated blood pressure, adverse metabolic markers, subclinical cardiovascular alterations, and clustering of cardiometabolic risk factors in children attending school. Particular attention is given to studies involving school-aged children because this developmental period offers an opportunity for early screening, prevention, and intervention before risk trajectories become biologically entrenched or clinically apparent in adulthood.

Materials and Methods: A systematic review approach was used to assemble and synthesize peer-reviewed evidence. The review question was structured around school-going children and adolescents, BMI or obesity exposure, and hypertension or cardiovascular risk outcomes. Evidence was drawn from major indexed literature and anchored to landmark systematic reviews, large pediatric observational studies, and contemporary reviews discussing obesity-related hypertension and cardiometabolic risk in childhood. Studies were prioritized if they reported blood pressure, lipid abnormalities, insulin resistance, left ventricular changes, vascular dysfunction, or clustered cardiovascular risk in relation to BMI. The review also considered pediatric blood pressure guideline context and the biological pathways linking excess adiposity to elevated blood pressure.

Result: The available evidence consistently shows a graded relationship between higher BMI and worse cardiovascular risk parameters in children. In a major systematic review and meta-analysis including 63 studies and 49,220 children, overweight and obese participants had significantly higher systolic and diastolic blood pressure than normal-weight peers, and obesity was additionally associated with worse lipid parameters, higher fasting insulin, greater insulin resistance, and increased left ventricular mass. Contemporary pediatric reviews also report that rising childhood obesity prevalence parallels increasing pediatric hypertension and that obesity-related hypertension is now recognized across both high-income and low- and middle-income settings.

Conclusion: BMI is a practical and clinically valuable screening measure for identifying school-going children at elevated risk of hypertension and cardiovascular abnormalities. Although BMI does not directly quantify body fat distribution, it remains strongly associated with blood pressure elevation and cardiometabolic risk clustering across pediatric populations. The evidence supports routine school and primary-care surveillance of BMI and blood pressure, early lifestyle intervention for children with overweight and obesity, and targeted cardiovascular risk evaluation in those with persistent adiposity.

Keywords: body mass index; childhood obesity; hypertension; cardiovascular risk; school-going children

Introduction

Childhood overweight and obesity have become major global public health concerns, with implications extending well beyond body size and appearance. In school-going children, excess adiposity is increasingly recognized as an early-life determinant of elevated blood pressure, metabolic dysfunction, vascular injury, and future cardiovascular disease. BMI remains the most widely used epidemiological and clinical index to classify excess weight in children because it is inexpensive, easily reproducible, and applicable in school screening programs. Although BMI does not directly measure adiposity or visceral fat, its widespread use has allowed large-scale studies to compare cardiovascular risk across categories such as normal weight, overweight, and obesity. The school-age period is particularly important because cardiovascular risk factors emerging at this stage often track into adolescence and adulthood.

This topic has gained greater importance after revised pediatric blood pressure guidelines lowered

normative cutoffs and emphasized repeated, accurate measurement. As discussed in recent pediatric nephrology literature, increasing obesity prevalence has coincided with increasing childhood hypertension prevalence, and this pattern is visible in both high-income and lower-resource settings.Obesity-related hypertension is now understood as a multifactorial condition involving sympathetic nervous system activation, insulin resistance, sodium retention, renin-angiotensin-aldosterone system activation, endothelial dysfunction, oxidative stress, inflammation, and sleep-disordered breathing. These mechanisms together promote persistent blood pressure elevation and early cardiovascular remodeling.

School-going children are an especially relevant target population because schools offer a practical platform for BMI surveillance, health education, dietary interventions, and physical activity promotion. School-based screening can identify children with both overt obesity and subtle upward BMI trajectories that might otherwise go unnoticed. Moreover, childhood is a period when lifestyle habits remain modifiable and before irreversible cardiovascular damage becomes widespread. Evaluating BMI associations with hypertension and cardiovascular risk in this age group therefore has implications for preventive pediatrics, school health policy, and long-term non-communicable disease control.

The present systematic review synthesizes the evidence on how BMI relates to hypertension and cardiovascular risks in school-going children. The review aims to summarize current knowledge, describe major observed associations, present tabulated observations useful for manuscript writing, and identify methodological strengths and gaps in the existing literature.

Materials & Method

This systematic review was prepared using a structured narrative synthesis model informed by the principles of systematic review methodology. The review question was: among school-going children, how is BMI associated with hypertension and cardiovascular risk markers? The population of interest included generally healthy school-going children and adolescents, broadly aged 5 to 18 years. The exposure was BMI expressed as continuous BMI, BMI percentile, BMI z-score, or weight-status categories such as normal weight, overweight, and obesity. Outcomes of interest included hypertension, elevated blood pressure, ambulatory blood pressure abnormalities, dyslipidemia, insulin resistance, impaired glycemic status, left ventricular hypertrophy or increased left ventricular mass, vascular dysfunction, and clustering of cardiovascular risk factors.

A literature search framework was developed around three conceptual domains: BMI or obesity, hypertension or blood pressure, and cardiovascular or cardiometabolic risk in children. Priority was given to systematic reviews, meta-analyses, large cross-sectional studies, cohort studies, and authoritative review articles. Sources were selected from indexed biomedical literature and complemented by relevant guideline-aware reviews discussing obesity-related pediatric hypertension and cardiometabolic risk.

Inclusion criteria:

- Included school-aged children or adolescents, usually 5-18 years.
- Reported BMI or BMI-derived categories.
- Evaluated blood pressure or cardiovascular risk outcomes.
- Used observational, longitudinal, cross-sectional, interventional baseline, or systematic review/meta-analytic designs.

Exclusion criteria:

- Studies focused exclusively on infants, preschool children, or adults.
- Studies without BMI-related exposure assessment.
- Reports lacking cardiovascular or blood pressure outcomes.
- Editorials, commentaries, or narrative pieces without primary evidence, unless used only for mechanistic context.
- Duplicate publications or studies with insufficient methodological detail.

Conceptual framework

The review was guided by a pathophysiological model in which increasing BMI serves as an accessible proxy for excess adiposity, which may contribute to elevated blood pressure and cardiovascular risk through interacting renal, neurohormonal, metabolic, inflammatory, and vascular mechanisms. This framework is consistent with recent pediatric hypertension literature highlighting the role of obesity in the contemporary rise of high blood pressure among children. The review also recognizes that BMI is imperfect; central adiposity, waist circumference, and body composition may better capture some aspects of risk, but BMI remains the most scalable measure for school and public health use.

Observation Tables

Table 1: Studies Linking BMI with Blood Pressure in School-Going Children

Author/year	Design	Population	BMI exposure	Key blood pressure finding
Friedemann et al., 2012	Systematic review and meta-analysis	49,220 children aged 5-15 years from 63 studies	Overweight and obesity vs normal weight	Overweight associated with +4.54 mm Hg systolic BP; obesity associated with +7.49 mm Hg systolic BP; diastolic BP also higher.
Myette and Flynn, 2024	Review	Children and adolescents	Excess body weight/obesity	Rising obesity prevalence parallels increasing childhood hypertension prevalence; obesity is a major contemporary driver of pediatric hypertension.
Obesity-related hypertension review, 2017	Review	Pediatric populations	Obesity/excess adiposity	Childhood obesity and hypertension frequently coexist and both track into adulthood with increased cardiovascular burden.
Performance of obesity indices meta-analysis, 2016	Systematic review and meta-analysis	Pediatric population	BMI and obesity indices	Obesity indices, including BMI-based measures, are useful for screening elevated BP in children and adolescents.

Table 2: BMI Associations with Cardiometabolic Risk Markers

Risk domain	Observation in higher BMI groups	Evidence
Lipids	Total cholesterol and triglycerides are higher in obese children than in normal-weight children.	Friedemann et al., 2012 systematic review/meta-analysis.
Insulin resistance	Fasting insulin and insulin resistance are significantly higher in obese children; overweight children show weaker or inconsistent changes	Friedemann et al., 2012
Glucose-metabolic dysfunction	Obese children display early metabolic derangements that support future cardiometabolic disease trajectories.	Review of cardiometabolic risk in obese children.
Clustered cardiometabolic risk	Excess adiposity in youth is associated with combined blood pressure, lipid, and metabolic risk rather than isolated abnormalities.	Pediatric obesity cardiovascular reviews.

Table 3: BMI-Related Target-Organ and Vascular Effects

Outcome	BMI-related pattern	Clinical implication
Left ventricular mass	Obese children had a significant increase in left ventricular mass compared with normal-weight peers.	Suggests early cardiac remodeling before adult disease manifests.
Ambulatory BP abnormalities	Higher BMI is associated with elevated ambulatory systolic BP and persistent BP burden.	Office BP alone may underestimate risk in obese children.
Endothelial and vascular dysfunction	Reviews describe early vascular injury, arterial stiffness, and endothelial impairment in obese youth.	Indicates preclinical cardiovascular damage at school age.
Target-organ injury risk	Obesity-related hypertension can promote early renal and cardiovascular consequences in childhood.	Supports earlier screening and follow-up.

Table 4: Screening and Prevention Implications in Children

Domain	Practical implication	Rationale
BMI surveillance	Regular BMI percentile assessment in schools and clinics	BMI is inexpensive, scalable, and associated with BP and cardiovascular risk.
Blood pressure monitoring	Repeated BP measurement is important in children with overweight or obesity	Single readings may misclassify status; obesity substantially raises risk of elevated

		BP.
Risk stratification	Children with obesity may merit evaluation for lipids, glucose metabolism, and organ effects	Cardiometabolic abnormalities frequently cluster with high BMI.
Lifestyle intervention	Diet, physical activity, sleep optimization, and family-based weight management should begin early	Obesity-related hypertension is modifiable and often begins during school years.

Result

The overall evidence base indicates a robust, graded, and clinically relevant association between increasing BMI and hypertension-related cardiovascular risk in school-going children. Across systematic reviews and pediatric observational literature, overweight children consistently show higher blood pressure than normal-weight peers, while obese children demonstrate still greater elevation. The most frequently cited quantitative evidence comes from the systematic review and meta-analysis by Friedemann et al., which found mean systolic blood pressure elevations of 4.54 mm Hg in overweight children and 7.49 mm Hg in obese children compared with normal-weight children. Similar trends were seen for diastolic blood pressure and ambulatory systolic blood pressure, supporting the consistency of the association across measurement approaches.

Obese children show less favorable total cholesterol and triglyceride levels, higher fasting insulin concentrations, and increased insulin resistance, indicating that BMI is closely linked to early cardiometabolic clustering rather than isolated hemodynamic change.In addition, obese youth demonstrate greater left ventricular mass, suggesting early structural cardiac adaptation to excess body size and blood pressure load. Reviews of pediatric cardiometabolic risk also describe endothelial dysfunction, vascular stiffness, and inflammatory-metabolic disturbance among children with obesity.

Recent literature continues to reinforce the centrality of obesity in pediatric hypertension epidemiology. The 2024 review by Myette and Flynn emphasizes that the rise in childhood obesity has been accompanied by increasing childhood hypertension prevalence worldwide and that recent studies after updated pediatric blood pressure guidelines still demonstrate a substantial obesity-hypertension link.This persistence across eras, populations, and definitions indicates that the association is unlikely to be an artifact of changing cutoffs alone.

A recurrent pattern across studies is dose response. Normal-weight children generally exhibit the most favorable cardiovascular profile, overweight children occupy an intermediate-risk position, and obese children have the highest burden of adverse blood pressure, metabolic, and structural outcomes. This gradient strongly supports the use of BMI as a triage marker in school health and primary care. While BMI cannot distinguish fat distribution or lean mass, the consistency of observed risk across multiple outcomes makes it a useful screening variable.

Not all children with elevated BMI exhibit identical risk, and heterogeneity is shaped by age, sex, pubertal status, ethnicity, physical activity, diet, sleep, and socioeconomic context. Nevertheless, the overall evidence clearly indicates that higher BMI in school-going children is associated with significantly greater risk of hypertension and early cardiovascular compromise.

Statistical Analysis: In the foundational meta-analysis, effect estimates were presented as weighted mean differences in cardiovascular risk parameters between BMI categories, allowing direct comparison of systolic blood pressure, diastolic blood pressure, lipids, insulin measures, and left ventricular mass between normal-weight, overweight, and obese groups. Multivariable regression is commonly used to adjust for age, sex, and pubertal stage, and some studies also consider physical activity, socioeconomic status, and waist measures. Cross-sectional datasets cannot fully establish temporal causation, and reverse behavioral associations are possible, though biologically less likely for blood pressure outcomes. Longitudinal studies are therefore more valuable for understanding persistence and future cardiovascular implications. Differences reported in pediatric BMI studies are likely to translate into meaningful public health consequences.

Discussion

Childhood obesity is now recognized as a major determinant of elevated blood pressure and early cardiovascular risk, and the available literature consistently shows that excess adiposity shifts children toward adverse hemodynamic and metabolic profiles. In comparing the present study with prior evidence, the most important point is that the observed association between higher body mass index and higher blood pressure is not isolated; rather, it fits a long-standing pattern documented across cross-sectional, cohort, and review-based studies. Friedemann et al. demonstrated in a large systematic review and meta-analysis of 63 studies involving 49,220 children that both overweight and obesity were associated with significantly higher systolic and diastolic blood pressure, with the effect size being greatest in obese children. If the present

study similarly found progressively higher blood pressure values across increasing BMI categories, that pattern is directly concordant with Friedemann et al., who concluded that cardiovascular risk parameters worsen substantially once BMI exceeds the normal range. Thus, the current findings may be interpreted not as a local phenomenon, but as part of a broader and reproducible biological relationship between adiposity and early cardiovascular stress.

A second important comparison concerns the contemporary relevance of obesity-related hypertension. Myette and Flynn emphasized in their 2024 review that rising obesity prevalence has been paralleled by an increase in childhood hypertension, and they specifically highlighted how newer pediatric blood pressure guidelines have improved recognition of affected children. Marcovecchio and Chiarelli likewise noted that obesity is a significant risk factor for hypertension in children and adolescents worldwide, with mechanisms involving sympathetic activation, renin-angiotensin-aldosterone system dysregulation, sodium retention, and renal compression by adipose tissue. When the present study demonstrates higher blood pressure among overweight or obese participants, it therefore aligns not only epidemiologically but also mechanistically with these recent reviews. Compared with older studies that focused largely on prevalence associations, current interpretations place greater emphasis on the pathophysiologic complexity of obesity-related hypertension, and the present study should be discussed within that modern framework. This makes the study clinically relevant because it supports the view that pediatric obesity is not merely a cosmetic or lifestyle issue, but a condition with direct cardiovascular implications detectable during childhood itself.

The findings of the present study may also be compared with classic prevalence studies such as that of Sorof et al., who reported that overweight status and ethnicity were strongly associated with hypertension in school-aged children. Although the available search results here provide bibliographic confirmation rather than detailed numeric extraction from the full paper, the study is widely recognized for showing that hypertension was more common in heavier children and that risk distribution varied across demographic groups. If the current study found a higher frequency of prehypertension or hypertension among overweight children, this would be in clear agreement with Sorof et al. However, if the present data were generated in a different ethnic or regional population, an important distinction is that the strength of association may vary according to background risk, dietary patterns, and body fat distribution, even while the overall direction remains the same. This comparative point is valuable because it allows the discussion to acknowledge both consistency with the literature and the possibility of population-specific magnitude differences.

A similar dose-response interpretation is supported by Friedemann et al. and by recent reviews, which show that cardiovascular risk intensifies as children move from overweight to obesity rather than remaining static across all excess-weight groups. Friedemann et al. reported that systolic blood pressure was higher by 4.54 mm Hg in overweight children and by 7.49 mm Hg in obese children compared with normal-weight peers, demonstrating a graded increase in risk with worsening adiposity. If the present study observed a stepwise rise in blood pressure across BMI strata, that would closely mirror this gradient and strengthen the argument for a quantitative relation rather than a simple binary association. On the other hand, if the present study identified only a modest or statistically limited difference between overweight and obese groups, this might reflect sample size, age structure, pubertal stage, or local environmental factors rather than a true contradiction of the larger evidence base. Therefore, the present results should be interpreted in relation to both the direction of association and the extent to which a BMI-related gradient was demonstrable in the study population.

The present study can also be compared with investigations that examined target-organ consequences of obesity-associated blood pressure elevation. Falkner et al. found that among African American adolescents, the prevalence of left ventricular hypertrophy was highest in those with both obesity and average blood pressure at or above 120/80 mm Hg, and the report emphasized independent as well as additive effects of obesity and high-risk blood pressure on left ventricular mass. This comparison is important even if the current study measured only BMI and blood pressure, because it suggests that the observed elevation in blood pressure may represent more than a transient numerical abnormality. In other words, if the present study detected higher blood pressure in obese children, Falkner et al. provide evidence that such findings may correspond to early structural cardiovascular remodeling in susceptible adolescents. The present study therefore supports the need for early screening and intervention, while the referenced work extends the significance of these findings from simple prevalence to subclinical cardiac injury.

Another meaningful comparison relates to the persistence and evolution of risk over time. Parker et al. examined change in weight status and development of hypertension, and this body of work is important because it moves beyond static associations to show that changing adiposity influences future blood pressure outcomes. Similarly, contemporary reviews indicate that both the degree and duration of obesity are important

determinants of hypertension risk, meaning that sustained excess adiposity confers more danger than a single elevated measurement alone. If the present study is cross-sectional, one limitation compared with such longitudinal literature is that it identifies association but cannot establish how long obesity has been present or whether blood pressure abnormalities will persist. Nevertheless, if the study found higher blood pressure among currently obese participants, it still reinforces the same preventive message: early weight gain should not be ignored because it may progress to established hypertension if uncorrected. This makes the present findings clinically useful even without follow-up data, especially in settings where routine pediatric cardiovascular surveillance is limited.

The broader cardiometabolic context is also relevant when comparing the present study with previous references. Friedemann et al. showed that obesity in children was associated not only with higher blood pressure but also with adverse lipid concentrations, higher fasting insulin, greater insulin resistance, and increased left ventricular mass. Marcovecchio and Chiarelli similarly described obesity-related hypertension as part of a wider metabolic and vascular disturbance rather than an isolated abnormality. Thus, if the current study focused principally on BMI and blood pressure, its findings still likely represent one visible component of a more extensive cardiometabolic risk cluster described in the literature. Compared with studies incorporating biochemical and echocardiographic endpoints, the present study may be narrower in scope; however, its importance remains substantial because blood pressure elevation is often the most accessible clinical marker for identifying children at heightened cardiovascular risk.

The current study should also be viewed in relation to severity-based frameworks of pediatric obesity. Recent reviews stress that the risk of hypertension rises with the degree of obesity, and severe obesity carries particularly high cardiovascular concern. This concept is consistent with the meta-analytic evidence showing stronger blood pressure differences in obese than overweight children, and it underscores why BMI categorization matters when interpreting pediatric findings. If the present study included relatively few severely obese participants, it may have underestimated the full burden of obesity-related hypertension compared with referral-based or tertiary-care cohorts. Conversely, if a high proportion of participants fell into higher BMI categories, the study's findings may appear stronger than community-based estimates, which would still be compatible with the literature because risk intensifies with severity. Such comparison helps place the present results within a clinical spectrum rather than treating all obesity as a homogeneous exposure.

From a public health perspective, the present findings are also comparable to the larger body of evidence indicating that childhood blood pressure elevation has implications extending into adult cardiovascular disease. Marcovecchio and Chiarelli stated that elevated blood pressure in childhood is consistently associated with cardiovascular disease in adulthood, supporting the importance of early detection and intervention. Friedemann et al. further argued that abnormal BMI in school-aged children substantially worsens cardiovascular risk parameters and may call into question whether traditional cutoffs adequately reflect risk in modern pediatric populations. Therefore, when the present study documents a relationship between obesity and blood pressure, it contributes to an evidence chain linking childhood adiposity to later cardiovascular burden rather than merely describing a temporary pediatric abnormality. Compared with highly specialized mechanistic studies, the present study may be more clinically pragmatic, but that pragmatism is valuable because it reflects the type of screening information available in everyday pediatric or school health settings.

Overall, the present study appears to be strongly consistent with the cited literature in demonstrating that overweight and obesity are associated with higher blood pressure and heightened cardiovascular risk in children and adolescents. Its findings resemble those of Friedemann et al. in supporting a graded relationship between excess adiposity and adverse blood pressure profiles, accord with Sorof et al. in showing a higher burden of hypertension among heavier school-aged children, and are clinically reinforced by Falkner et al., who linked the coexistence of obesity and high-risk blood pressure to left ventricular hypertrophy. At the same time, the present study may differ from some references in design, population, and available endpoints, especially if it lacks longitudinal follow-up, metabolic markers, or target-organ assessment. These differences do not weaken its contribution; instead, they define its place within the literature as practical evidence that the obesity-hypertension relationship is observable across diverse pediatric settings. The comparative interpretation therefore supports a clear clinical message: children with elevated BMI should be actively screened for blood pressure abnormalities, and early intervention is justified because the literature consistently shows both immediate and long-term cardiovascular consequences.

The review also highlights several methodological considerations. Many available studies are cross-sectional, which limits causal inference. Definitions of hypertension and obesity vary across studies and eras, and some studies use office blood pressure without confirmation by repeated or ambulatory methods. Pubertal status, ethnicity, socioeconomic

adversity, and environmental exposures are not always uniformly accounted for. Even so, the consistency of the association across populations and cardiovascular domains makes the central conclusion highly stable.

Conclusion

To conclude, prevention and early intervention are the most actionable implications. School-based nutrition support, physical activity promotion, sleep hygiene, family-centered weight management, reduced exposure to ultra-processed foods, and regular health screening may reduce both current and future cardiovascular burden. For research, there is a need for more longitudinal studies that integrate BMI with waist measures, body composition, ambulatory blood pressure, imaging markers, and transition-to-adulthood outcomes. Until then, the present body of evidence firmly supports the use of BMI as a key screening and risk-stratification marker for hypertension and cardiovascular risk among school-going children.

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