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Original Research Article

Early Indicators of Metabolic Risk: A Study on Anthropometric and Cardiovascular Parameters in Primary School Children

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Abstract:

Background: The rising prevalence of childhood obesity and metabolic abnormalities represents a growing public health concern, particularly in low- and middle-income countries. Early metabolic risk often manifests during childhood through subtle anthropometric and cardiovascular changes that precede clinically apparent disease. Identifying these early indicators is essential for timely prevention of future cardiometabolic disorders.

Objectives: To assess anthropometric and cardiovascular parameters among primary school children aged 6–12 years and to analyze the relationship between these parameters as early indicators of metabolic risk.

Methods: Over the course of six months, a cross-sectional observational study was carried out via a school health program connected to a tertiary care hospital. A total of 250 children aged 6–12 years were enrolled after obtaining parental consent. Height, weight, BMI, waist circumference, hip circumference, neck circumference, waist-to-hip ratio, and waist-to-height ratio were among the anthropometric measurements. Cardiovascular parameters assessed were systolic and diastolic blood pressure, resting pulse rate, oxygen saturation (SpO_2), and perfusion index. Statistical analysis involved descriptive statistics and correlation analysis to evaluate associations between anthropometric and cardiovascular variables.

Results: The study revealed diversity in anthropometric and cardiovascular indicators, with 9.2% of the 250 participants being obese and 18.4% being overweight. Systolic blood pressure was significantly positively correlated with central adiposity measurements, including waist-to-height ratio ($r = 0.45, p < 0.001$), waist circumference ($r = 0.41, p < 0.001$), and neck

circumference ($r = 0.38, p < 0.001$). The waist-to-height ratio had a stronger association with systolic blood pressure ($r = 0.45$) than body mass index ($r = 0.32$). Moreover, 22.8% of patients had a waist-to-height ratio ≥ 0.5, indicating increased metabolic risk. While most children had normal oxygen saturation values (mean $98.1\% \pm 1.2\%$), 11.6% had blood pressure readings over the 90th percentile, which suggests an early risk of cardiovascular disease.

Conclusion: Simple anthropometric and cardiovascular measurements can serve as effective early indicators of metabolic risk in primary school children. Central adiposity measures demonstrate stronger associations with cardiovascular parameters than body mass index alone. Integrating these assessments into routine school health screening programs may facilitate early identification and prevention of future cardiometabolic diseases.

Keywords: Childhood obesity; metabolic risk; anthropometry; blood pressure; school health screening; cardiovascular parameters.

Introduction

Childhood Metabolic Risk: A Growing Concern

Childhood obesity and metabolic illnesses are now major worldwide problems with far-reaching long-term effects. The course of these disorders indicates that childhood health problems often carry over into adulthood, resulting in a vicious circle of chronic illness. Over 340 million children and adolescents worldwide are estimated by the World Health Organization to be overweight or obese, and this figure is continuously rising [1]. Although this demographic change was previously seen to be a problem for high-income countries, it is now rapidly spreading to low- and middle-income countries. The prevalence of pediatric obesity has increased in countries like India due to fast urbanization, dietary changes toward foods high in energy, and a noticeable decline in physical activity [2]. This is especially troubling because childhood obesity is not just a cosmetic issue; it is strongly associated with insulin resistance, dyslipidemia, hypertension, and early atherosclerosis changes. The severity of this development is shown by longitudinal studies, which demonstrate that children who are overweight are much more likely to become obese adults, increasing their lifetime risk of type 2 diabetes and cardiovascular disease [3]. This trend's subtlety is its most harmful feature; metabolic risk often appears silently in childhood, underscoring the critical need for early detection before irreversible physiological injury occurs.

Role of Anthropometric Indicators

Anthropometric assessments provide a useful, non-invasive, and affordable way to assess body composition and fat distribution in settings with limited resources in the pursuit of early detection. Overweight and obesity in pediatric populations have historically been classified using the Body Mass Index (BMI). BMI is a surrogate measure of weight in relation to height and can not differentiate between lean muscle mass and fat mass, therefore it may not adequately represent the subtlety of central adiposity, which is more closely associated with metabolic risk [4]. Abdominal fat gain, which is frequently concealed in kids with "normal" BMIs, may be a more reliable indicator of health problems, according to new research. This accumulation of abdominal fat is accurately reflected by measurements such as waist circumference and waist-to-hip ratio, which have been shown to have a higher link with insulin resistance and cardiovascular risk factors than BMI alone [5]. Additionally, the waist-to-height ratio which has a suggested cut-off value of 0.5 indicating higher cardiometabolic risk has

garnered particular attention due to its simplicity of use and applicability across various age groups [6]. Furthermore, neck circumference is becoming recognized as a novel anthropometric indicator of subcutaneous fat in the upper body. According to studies, it is a helpful screening tool in field settings, associated with metabolic syndrome, obesity, and hypertension in both adults and children, and provides a straightforward substitute when measuring the waist is challenging [7].

Cardiovascular Parameters as Early Indicators

Physiological alterations in the cardiovascular system are important early warning indicators that go beyond physical measurements. Excessive obesity in children often results in cardiovascular changes that can cause disease. The development of adult hypertension and cardiovascular morbidity is known to be highly correlated with childhood increased blood pressure [8]. Studies consistently show that children with central obesity and excessive BMI have greater systolic and diastolic blood pressure than their counterparts who are slimmer [9]. These increases indicate a change in the body's hemodynamic baseline even if they do not reach the threshold for clinical hypertension. In addition to blood pressure, the resting pulse rate is a useful indicator of autonomic balance and general cardiovascular health. Additionally, non-invasive measurements like perfusion index and oxygen saturation (SpO_2) offer information about peripheral circulation and microvascular function, which may be somewhat changed in the early phases of metabolic dysregulation [10].

Indian Context and Rationale

The "double burden" of malnutrition is a peculiar public health conundrum that exists in India. This has to do with the fact that undernutrition and childhood obesity are coexisting in the same community. Due to increasingly sedentary lifestyles, more screen time, and easy access to processed meals high in caloric energy, school-age children in urban and semi-urban areas are especially susceptible to this shift [11]. Information about the interaction between anthropometric and cardiovascular markers of metabolic risk in Indian primary school students is still lacking, despite this increasing hazard [12]. The information on the relationship between blood pressure and particular central adiposity markers in this particular population is lacking. The best way to find children who are at risk and start preventative actions before clinical disease manifests is through early school-based screening. The rising incidence of cardiometabolic disease may be successfully reduced by integrating fundamental anthropometric and cardiovascular evaluations into routine school health programs [13].

Objectives

The present study was undertaken with the following objectives:

- To measure six to twelve-year-old primary school pupils' height, weight, BMI, waist circumference, hip circumference, neck circumference, waist-to-hip ratio, and waist-to-height ratio.
- To evaluate cardiovascular parameters such as perfusion index, resting pulse rate, systolic and diastolic blood pressure, and SpO_2.
- To examine the connection between cardiovascular measures and anthropometric indices as early markers of metabolic risk.
- To produce baseline data in order to assist initiatives for school-based metabolic risk screening.

Methodology

Study Design and Duration

This was a cross-sectional observational study conducted over a period of six months.

Study Setting

A tertiary care hospital-linked outreach program including certain elementary schools

serving urban and semi-urban populations was used to conduct the study. In order to protect the children's privacy and comfort, data collecting was done in a specific location during school hours.

Study Population

The study population consisted of primary school children aged 6–12 years enrolled in Classes 1–6.

Sample Size Estimation

A minimal sample size of 225 was determined to reach 80% power at a 95% confidence level based on prior research showing moderate correlations between anthropometric parameters and blood pressure (r = 0.3). A final sample size of 250 children was included, accounting for partial and non-response data [14].

Inclusion and Exclusion Criteria

Children between the ages of six and twelve who had written informed agreement from their parents or legal guardians were included. Children with endocrine abnormalities, diabetes mellitus, congenital heart disease, or those using drugs that impact blood pressure, growth, or metabolism were not included.

Data Collection Instruments

A pre-tested, structured questionnaire and case record form were used to gather data. Parents or guardians provided information on sociodemographic traits, eating habits, physical activity patterns, sleep duration, and family history of metabolic diseases.

Anthropometric Measurements

A calibrated digital weighing scale was used to record weight, and height was measured to the nearest 0.1 cm using a stadiometer. BMI was calculated by dividing height in meters squared by weight in kilos, and it was then interpreted using age and sex-appropriate percentiles. A non-stretchable measuring tape was used to measure the circumferences of the waist, hip, and neck in accordance with WHO guidelines. Accordingly, waist-to-hip and waist-to-height ratios were calculated [15].

Cardiovascular Measurements

A pediatric digital sphygmomanometer with suitably sized cuffs was used to take the blood pressure. After the kid had relaxed, two readings were taken at intervals of five minutes, and the average was noted. Under standardized settings, a pulse oximeter was used to quantify the resting pulse rate, SpO_2, and perfusion index.

Ethical Considerations

The tertiary care hospital's Institutional Ethics Committee granted ethical approval. Children who participated offered verbal assent, and parents or guardians gave written informed consent. Data confidentiality was rigorously respected.

Statistical Analysis

The data was entered into Microsoft Excel and analyzed using SPSS version 26. While continuous variables were displayed as mean ± standard deviation, categorical variables were displayed as frequencies and percentages. The correlations between anthropometric and cardiovascular variables were evaluated using Pearson or Spearman correlation coefficients. Age and sex were taken into account using multiple linear regression analysis. A p-value of less than 0.05 was considered statistically significant [16].

Results

The analysis comprised 250 elementary school students between the ages of 6 and 12. Children from both urban and semi-urban backgrounds, representing all primary school grades, made up the study population. Age-related differences were seen in anthropometric and cardiovascular measures, which also revealed significant correlations suggestive of early metabolic risk.

Socio-demographic Characteristics

The study effectively recruited and examined data from 250 primary school pupils,

offering a glimpse into the health of kids between the ages of 6 and 12. The participants' average age was 9.1 ± 1.8 years, and their gender distribution was fairly balanced, with boys accounting for 51.2% of the group and girls for 48.8%. The vast majority of these kids (64.8%) were from urban residential areas, while the remaining 35.2% were from semi-urban settings. This urban dominance is important because it frequently corresponds with the lifestyle characteristics that were previously highlighted, such as increased consumption of processed foods and decreased outdoor play.

It's interesting to note that the medical history and family structure offered some instructive background. The majority of the kids were from nuclear families, which occasionally have distinct effects on food preferences and activity tracking than joint family arrangements. The high frequency of metabolic problems in the immediate family was possibly the most alarming result in the demographic data. About 27.2% of the kids had a family history of diabetes, and 23.6% had a family history of high blood pressure. Given that a quarter of these kids may already be genetically predisposed to metabolic hazards, it is even more important to keep an eye on their cardiovascular and physical signs. These sociodemographic characteristics depict a young population that is already negotiating a genetic heritage and environment that promote metabolic dysregulation.

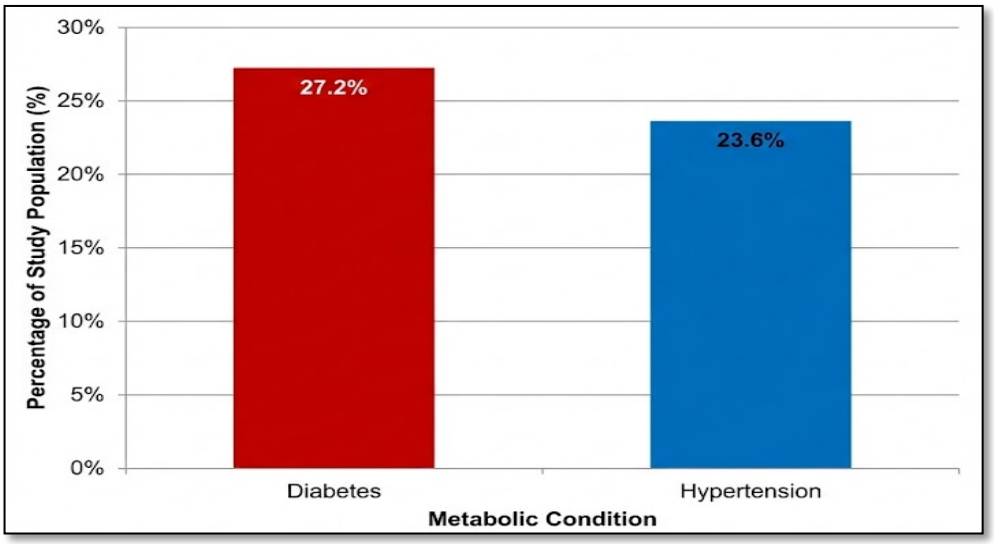

Figure 1 Prevalence of parental history of metabolic diseases among the study participants

Table 1 Socio-demographic characteristics of the study population (n = 250)

Variable	Frequency (n)	Percentage (%)
Age group (years)		
6–8	82	32.8
9–10	94	37.6
11–12	74	29.6
Sex		
Male	128	51.2
Female	122	48.8
Residential area		
Urban	162	64.8
Semi-urban	88	35.2
Family history of diabetes	68	27.2
Family history of hypertension	59	23.6

Anthropometric Profile

A notable shift in nutrition was revealed when we examined the children's body measures. The fact that 61.6% of the kids had the proper nutritional status is positive, but the other data suggested that overnutrition was on the rise. In particular, according to the usual WHO BMI-for-age percentiles, 18.4% of the participants were classed as overweight and 9.2% as obese. This indicates that about one-third of the kids in this group are overweight, which is a significant risk factor for health problems down the road. The average weight and height were 32.1 kg and 132.4 cm, respectively, but the wide variation was indicative of the fast growth phases that take place between the ages of 6 and 12.

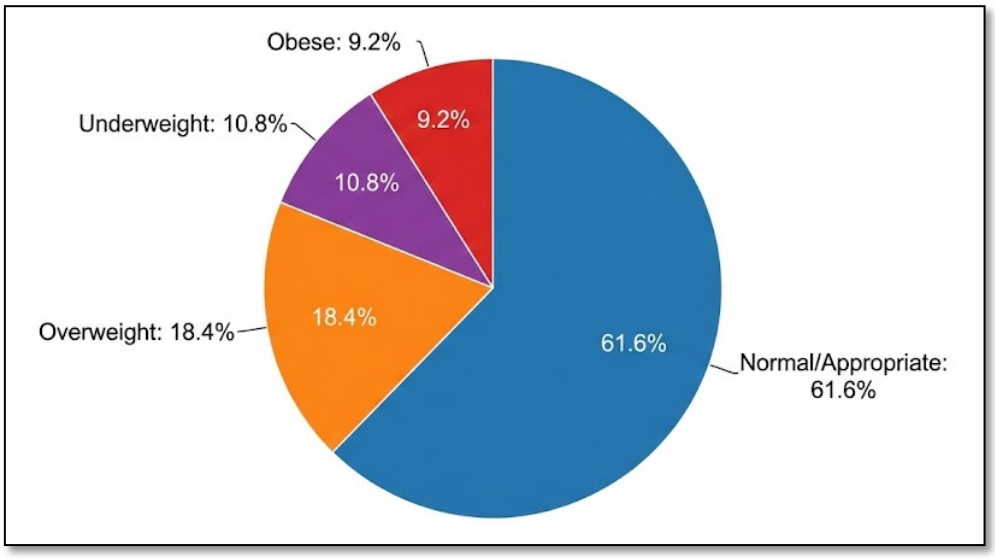

Figure 2 Distribution of nutritional status based on BMI

BMI, however, did not provide a whole picture. In order to identify "hidden" dangers, we went deeper utilizing central adiposity metrics. WHtR, or the waist-to-height ratio, was especially instructive. A noteworthy 22.8% of the patients exhibited a WHtR of at least 0.5. This is an important discovery since a ratio greater than 0.5 is a powerful sign of increased metabolic risk, indicating that the rate of accumulation of abdominal fat is faster than vertical growth. Additionally, the average waist circumference was 63.7 cm, while some children had waist circumferences as high as 89.0 cm. By using these central adiposity metrics, we were able to find more children at risk who could have gone unnoticed if we had only used BMI. This disparity between BMI and central fat measurements emphasizes how crucial it is to include fat distribution rather than just overall weight when evaluating a child's health.

Table 2 Distribution of anthropometric parameters among study participants

Parameter	Mean ± SD	Minimum	Maximum
Height (cm)	132.4 ± 12.6	108.2	158.6
Weight (kg)	32.1 ± 9.4	17.5	58.2
Body Mass Index (kg/m²)	17.9 ± 3.1	13.2	26.4
Waist circumference (cm)	63.7 ± 8.5	48.0	89.0
Hip circumference (cm)	71.2 ± 9.1	55.3	97.4
Neck circumference (cm)	27.8 ± 3.2	22.0	35.6
Waist-to-hip ratio	0.89 ± 0.06	0.76	1.02
Waist-to-height ratio	0.48 ± 0.06	0.38	0.63

Cardiovascular Parameters

The cardiovascular assessment offered insight into how the children's heart health might be impacted by these physical changes. We found that blood pressure levels progressively rose with age, as would be expected in an expanding population. The average diastolic blood pressure was 66.8 mmHg and the average systolic blood pressure was 104.6 mmHg. A worrying portion of the kids did not keep their blood pressure measurements within the typical physiological range for their height and age, even though the majority of them did. In particular, 11.6% of the kids had high blood pressure, which is defined as being in the 90th percentile or higher for their age and gender. This implies that the cardiovascular system is already under more stress than ideal for over 10% of children.

With a mean SpO_2 of 98.1%, the children typically demonstrated healthy oxygenation in terms of other measures. The majority of participants' oxygen saturation values remained within normal physiological ranges, demonstrating the integrity of their basic circulatory and respiratory systems. The perfusion index, which measures the pulse strength at the sensor site, varied widely, ranging from 1.2 to 8.9. Even while the majority of the kids were in good health, it is concerning that some of them had high blood pressure. Long before maturity, it acts as a subtle, silent warning that the physiological burden of weight and lifestyle variables is starting to show up in the cardiovascular system.

Table 3 Cardiovascular parameters of the study population

Parameter	Mean ± SD	Minimum	Maximum
Systolic BP (mmHg)	104.6 ± 10.8	82	132
Diastolic BP (mmHg)	66.8 ± 8.2	50	88
Resting pulse rate (beats/min)	86.4 ± 9.7	62	112
SpO_2 (%)	98.1 ± 1.2	94	100
Perfusion index	4.2 ± 1.6	1.2	8.9

Association Between Anthropometric and Cardiovascular Parameters

Understanding the connection between heart health and body form was the main goal of our investigation, and the findings were very instructive. Measures of obesity and blood pressure showed statistically significant positive relationships, according to correlation analysis. In other words, blood pressure rose in tandem with body measurements. But not every measurement was a reliable predictor. In comparison to BMI, we discovered that central obesity indicators had substantially stronger correlations with systolic blood pressure. The correlation coefficient (r) for the Body Mass Index was 0.32, indicating a modest level of linkage.

The waist-to-height ratio, on the other hand, showed the highest connection with systolic blood pressure ($r = 0.45$), closely followed by neck circumference ($r = 0.38$) and waist circumference ($r = 0.41$). This is an important distinction. It suggests that the location of the fat is more important than the child's overall weight. Central adiposity measures appear to be more accurate than BMI alone in predicting early cardiovascular risk, as seen by the greater statistical correlation between central fat (neck and belly) and blood pressure. The biological plausibility that visceral fat increases the metabolic and hemodynamic burden on the developing organism is well supported by the facts. These results confirm that a straightforward tape measure is an effective tool for early risk assessment in educational environments.

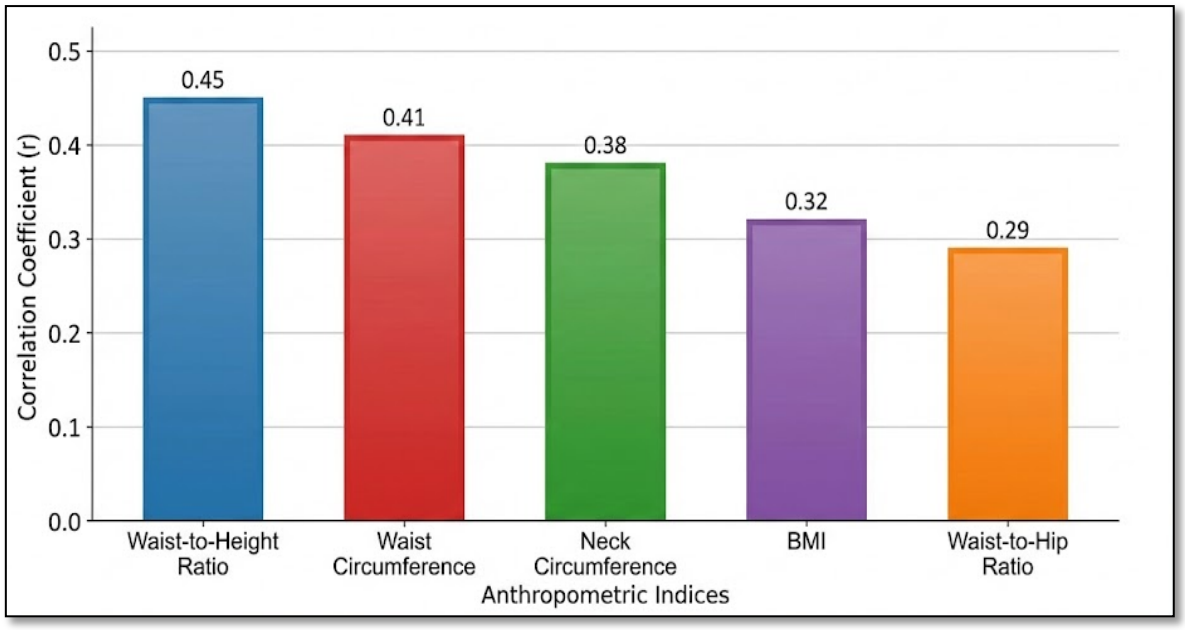

Figure 3 Correlations between anthropometric measures and systolic blood pressure

Table 4 Cardiovascular parameters of the study population

Anthropometric parameter	Correlation coefficient (r)	p-value
Body Mass Index	0.32	< 0.001
Waist circumference	0.41	< 0.001
Neck circumference	0.38	< 0.001
Waist-to-height ratio	0.45	< 0.001
Waist-to-hip ratio	0.29	0.002

Discussion

Early Metabolic Signals in Childhood

The current study highlights the presence of early anthropometric and cardiovascular alterations in elementary school pupils that could be important but subtle markers of metabolic risk. Our findings support the need for caution during the primary school years by indicating that the physiological effects of excess weight start to show well before maturity. This finding is consistent with the medical literature's general agreement that childhood obesity is inextricably connected to new cardiovascular risk factors that demand for early detection and treatment [17]. In particular, our study's relationships between high blood pressure and central adiposity markers are consistent with findings from past pediatric studies that have repeatedly emphasized the hemodynamic burden of belly fat [18]. These results imply that youth metabolic health is not binary but rather occurs on a continuum where even small changes in body composition can cause quantifiable cardiovascular reactions.

Comparative Efficacy of Anthropometric Indices

The differing sensitivity of several body measures in predicting health risks is a crucial finding from this study. Despite its widespread use as a general screening tool, BMI showed less correlation with cardiovascular parameters than assessments of fat distribution such as waist circumference and waist-to-height ratio. This disparity supports growing evidence that visceral fat surrounding the abdominal organs, or core obesity, is more significant for predicting metabolic risk than overall adiposity or straightforward weight-for-height measurements [19]. Additionally, neck

circumference shown a substantial connection with blood pressure, indicating that it is a valuable and instructive parameter. It is a very promising tool for mass screening programs where waist measurement may be logistically challenging due to its strong correlation with cardiovascular stress and ease of assessment in field situations.

Clinical Implications and Future Risk

An important finding for public health is the discovery of high blood pressure in a subset of otherwise healthy youngsters. These early blood pressure elevations should be addressed carefully even in high-normal ranges because they may last into adulthood and eventually increase the risk of cardiovascular disease tenfold [20]. The validity of these findings is reinforced by the study's established measurement techniques and comprehensive assessment of anthropometric and cardiovascular traits. It is crucial to recognize some limitations, though. For example, the cross-sectional design restricts our ability to draw conclusive causal inferences regarding the progression of these risk factors, and the absence of physiological indicators such as fasting glucose and lipid profile prevents a full assessment of the metabolic syndrome. However, the information offers a convincing starting point for introducing more focused health monitoring in schools.

Conclusion

This cross-sectional study offers strong proof that simple anthropometric and cardiovascular tests can effectively identify early indicators of metabolic risk in primary school pupils. According to the data, there is detectable physiological strain associated with the increased prevalence of childhood obesity, particularly higher blood pressure, which is substantially correlated with measures of central adiposity such as neck circumference and waist-to-height ratio.

These discoveries have practical relevance. BMI is not enough to identify children who are at risk. A useful tactic is to incorporate non-invasive examinations, including measurements of the waist and neck circumference, into routine school health programs. These instruments are inexpensive, simple to use, and more sensitive to the particular dangers associated with central fat. Early detection of these "silent" dangers allows schools and medical professionals to start timely preventative measures. In the end, by addressing the underlying reasons during the early years of life, this proactive strategy may considerably reduce the burden of cardiometabolic disease in the future.

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