

Association of platelet distribution width with left ventricular remodeling in children with primary hypertension: a body mass index–matched case–control study

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Abstract

Background

Platelet distribution width (PDW) is a routinely available marker of platelet size heterogeneity, but its association with cardiac remodeling in pediatric hypertension is unclear. We assessed the associations of PDW with left ventricular remodeling (LVR) and left ventricular mass index (LVMI), and its incremental discriminatory value.

Methods

This retrospective, single-center, BMI-matched case–control study included 126 treatment-naïve children with primary hypertension, comprising 63 children with LVR and 63 matched controls with normal left ventricular geometry. LVR was defined as any abnormal left ventricular geometry, including concentric remodeling, concentric hypertrophy, or eccentric hypertrophy. Controls were selected using 1:1 optimal matching without replacement, with exact matching on age and sex and minimization of BMI differences. Conditional logistic regression and linear regression were used to assess the associations of PDW with LVR and LVMI, respectively. Receiver operating characteristic curve analysis and the DeLong test were used to evaluate changes in discrimination after adding PDW to the clinical models.

Results

PDW was higher in children with LVR than in matched controls (12.22 ± 1.44 vs. 11.13 ± 1.18 fL; $P < 0.001$). Each 1-fL increase in PDW was associated with higher odds of LVR after adjustment for hypertension grade, obstructive sleep apnea syndrome, and visceral adiposity index (OR, 1.523; 95% CI, 1.105–2.100; $P = 0.010$) and after additional adjustment for erythrocyte sedimentation rate and parental history of hypertension (OR, 1.526; 95% CI, 1.094–2.129; $P = 0.013$). In the matched sample, higher PDW was associated with higher LVMI ($\beta = 1.77 \text{ g/m}^{2.16}$ per 1-fL increase; $P = 0.002$). Adding PDW increased the AUC from 0.703 to 0.791 in the prespecified clinical model (DeLong $P = 0.009$) and from 0.730 to 0.803 in the extended model (DeLong $P = 0.013$).

Conclusions

Higher PDW was associated with LVR after multivariable adjustment and with higher LVMI in the matched sample. PDW also improved discrimination beyond the evaluated clinical models; however, these findings require prospective external validation.

Background

Primary hypertension in childhood frequently persists into adulthood and may be accompanied by early hypertension-mediated target-organ damage, particularly increased left ventricular mass and abnormal left ventricular geometry^[1–3]. Although elevated blood pressure and hemodynamic load are central determinants of LVR, variability in cardiac structure among children with similar blood pressure levels suggests that additional metabolic, inflammatory, or hematologic factors may also be involved^[4, 5].

A key difficulty in elucidating additional factors associated with LVR in children is the substantial confounding influence of obesity. Obesity is closely intertwined with blood pressure load and is associated with a broad metabolic profile that may mask other remodeling-related signals^[5]. This may complicate the identification of factors independently linked to cardiac remodeling beyond obesity-related metabolic effects. Standard statistical adjustment for body mass index (BMI) alone may not fully account for residual confounding arising from overall body size and obesity-associated metabolic traits.

Platelet indices derived from routine complete blood counts have recently drawn interest as readily accessible surrogates of platelet heterogeneity. Among them, platelet distribution width (PDW) reflects the degree of variation of size in platelets^[6]. PDW and other platelet volume indices have been linked with left ventricular dysfunction, left ventricular hypertrophy, and other detrimental cardiovascular outcomes in adult populations^[7, 8]. However, these findings cannot be directly extrapolated to children because adult populations differ in age, comorbidity, and cumulative cardiovascular disease burden. In children with primary hypertension, PDW has been associated with a non-dipping blood pressure pattern^[9]; however, data regarding its potential association with cardiac structural remodeling remains scarce, particularly in a BMI-matched setting.

To examine this question while enhancing comparability with regard to overall body size, we performed a 1:1 BMI-matched case–control study in previously untreated children with primary hypertension. Controls were selected using optimal matching without replacement, with precise matching for age and sex and minimization of differences in overall BMI. The primary objective was to assess the association between PDW and LVR after adjustment for relevant clinical factors. We additionally examined the association between PDW and LVMI as a secondary exploratory analysis and assessed whether adding PDW improved discrimination beyond the evaluated clinical models.

Methods

Study design and participants

We performed a retrospective, single-center, matched case-control study at Beijing Children's Hospital, National Center for Children's Health, Beijing, China. The study was approved by the Medical Ethics Committee of Beijing Children's Hospital, Capital Medical University (approval no. [2024]-Y-112-D). The requirement for informed consent to participate was waived by the committee because of the retrospective study design. All data were anonymized before analysis, and the study was conducted in accordance with the Declaration of Helsinki.

We examined the electronic medical records of children and adolescents aged 9–17 years who received their initial documented diagnosis of primary hypertension at our institution between January 2021 and September 2025. Treatment-naïve status was confirmed from documented medication histories and reconciliation at admission; no participant had documented prior exposure to antihypertensive agents. All laboratory tests, ambulatory blood pressure monitoring, polysomnography, and echocardiographic examinations included in the analysis were conducted as part of the standard clinical assessment prior to the commencement of antihypertensive therapy.

Children who exhibited any abnormal left ventricular geometry, concentric remodeling, concentric hypertrophy, or eccentric hypertrophy, were defined as having left ventricular remodeling (LVR). All 63 eligible children presenting with LVR were enrolled as cases. Controls were identified from those with normal left ventricular geometry via 1:1 optimal matching without replacement, with precise matching for age and sex and reduced differences in overall BMI. The final matched set contained 126 participants, including 63 LVR children and 63 matched controls with normal left ventricular geometry.

The exclusion criteria applied were: (1) presence of secondary hypertension; (2) congenital heart disease, cardiomyopathy, or other structural cardiac anomalies; (3) chronic kidney disease; (4) systemic inflammatory or autoimmune conditions, including systemic lupus erythematosus and Kawasaki disease; (5) acute infection occurring within the prior 2 weeks; (6) malignancy; (7) known use of medications that may affect platelet parameters, e.g., aspirin or systemic corticosteroids; and (8) incomplete clinical, laboratory, or echocardiographic data necessary for the analysis.

Anthropometric and clinical measurements

Anthropometric parameters, including weight, height, and waist circumference (WC), were measured according to standardized protocols. BMI was calculated as weight in kilograms divided by height in meters squared. The Visceral Adiposity Index (VAI) was computed using sex-specific published formulas that incorporate WC and lipid levels.

Ambulatory blood pressure monitoring (ABPM) was conducted with a validated oscillometric monitor (Spacelabs Healthcare, Redmond, Washington, USA) following the 2014 American Heart Association guidelines, which are consistent with international recommendations^[12]. The monitoring intervals were programmed to 20 min during daytime and 30 minutes at nighttime.

Clinical definitions

Primary hypertension was established based on the 2016 European Society of Hypertension (ESH) guideline and the 2022 European Society of Cardiology (ESC) consensus on hypertension in children and adolescents. In participants younger than 16 years, hypertension was diagnosed when office systolic and/or diastolic blood pressure (BP) readings at or above the 95th percentile for sex, age, and height. Grade 1 hypertension was defined as BP values between the 95th and 99th percentile plus 5 mmHg, whereas grade 2 hypertension was defined as BP values exceeding the 99th percentile plus 5 mmHg. For

participants aged ≥ 16 years, hypertension corresponded to office blood pressure $\geq 130/85$ mmHg, in accordance with the 2022 consensus statement. The diagnosis of hypertension was confirmed by elevated office BP measurements obtained on at least three separate visits after excluding secondary causes of hypertension^[1, 10]. Obesity was defined according to the World Health Organization (WHO) growth reference for children and adolescents aged 5–19 years as a BMI-for-age value > 2 standard deviations above the reference median^[11]. A non-dipping BP pattern was defined as a nocturnal reduction in systolic and/or diastolic BP of $< 10\%$ compared with the corresponding daytime BP values^[12]. All participants underwent overnight polysomnography as part of the baseline clinical evaluation. Obstructive sleep apnea syndrome (OSAS) was defined as an obstructive apnea–hypopnea index (OAHl) ≥ 1 event/hour^[13, 14].

Echocardiography

Echocardiographic studies were conducted by trained pediatric sonographers with a Vivid E95 system (GE Healthcare, Horten, Norway). Left ventricular mass (LVM) was derived from the Devereux-modified cube formula and normalized to height^{2.16} to derive the LVMI. Left ventricular hypertrophy (LVH) was diagnosed as an LVMI of ≥ 45 g/m^{2.16}^[1, 10].

Relative wall thickness (RWT) was derived using the formula $(IVSd + PWTd)/LVEDD$. Age-adjusted RWT (RWTa) was obtained as $RWT - 0.005 \times (age - 10)$, with a value ≥ 0.38 considered elevated. Left ventricular geometry was categorized into normal (LVMI < 45 g/m^{2.16} and RWTa < 0.38), concentric remodeling (LVMI < 45 g/m^{2.16} and RWTa ≥ 0.38), concentric hypertrophy (LVMI ≥ 45 g/m^{2.16} and RWTa ≥ 0.38), and eccentric hypertrophy (LVMI ≥ 45 g/m^{2.16} and RWTa < 0.38). LVR was defined as any abnormal geometry pattern, whereas normal geometry was used as the reference category.

Laboratory measurements

Fasting venous blood specimens were drawn during the morning following an overnight fast. Whole-blood specimens for complete blood cell counts were obtained in EDTA-containing tubes and processed within 2 hours following venipuncture with an automated hematology analyzer (Sysmex Corporation, Kobe, Japan). The platelet-associated parameters comprised platelet count, mean platelet volume (MPV), and platelet distribution width (PDW).

Serum samples for biochemical analyses were prepared per standard institutional protocols. Lipid profile parameters, fasting glucose, and serum uric acid were measured with an automated biochemical analyzer (Hitachi High-Tech Corporation, Tokyo, Japan). Fasting insulin concentrations were determined using a standard immunoassay, and erythrocyte sedimentation rate (ESR) was assessed using routine laboratory procedures.

Statistical analysis

Continuous variables were summarized as mean $\pm$ standard deviation (SD) or median (interquartile range [IQR]), as appropriate, and categorical variables as counts and percentages. Between-group comparisons were performed using paired t tests or Wilcoxon signed-rank tests for continuous variables and McNemar tests for categorical variables. Post-matching balance was assessed using standardized mean differences (SMDs), with an absolute SMD < 0.10 considered indicative of adequate balance.

The association between PDW and LVR was evaluated using conditional logistic regression to account for the matched design. PDW was modeled continuously per 1-fL increase, and the results are reported as odds ratios (ORs) with 95% confidence intervals (CIs). Two hierarchical covariate-adjustment models were fitted. Model 1 included hypertension grade, OSAS, and VAI, whereas Model 2 additionally included ESR and parental history of hypertension. Given the residual post-matching imbalance in VAI, a sensitivity analysis was performed using Model 2 without VAI. In exploratory analyses, MPV was evaluated as the sole platelet index and jointly with PDW in models adjusted for hypertension grade, OSAS, and VAI.

The association between PDW and LVMI was evaluated using linear regression. PDW was examined both continuously and across quartiles. For the quartile analysis, PDW quartiles were entered as an ordinal variable to test for trend. Regression coefficients with 95% CIs are reported.

The discriminatory performance of PDW alone was evaluated using receiver operating characteristic (ROC) curve analysis, with calculation of the area under the curve (AUC) and its 95% CI. The optimal cutoff was determined using the Youden index, and the corresponding sensitivity and specificity were reported. The incremental discriminatory value of PDW was assessed by comparing each clinical model with the corresponding model after the addition of PDW. Differences in AUC were evaluated using the DeLong test. Integrated discrimination improvement (IDI) and continuous net reclassification improvement (NRI) were also calculated. The 95% CIs for the single-marker AUC, Δ AUC, IDI, and continuous NRI were estimated using 1,000 bootstrap resamples.

All tests were two-sided, and $P < 0.05$ was considered statistically significant. Statistical analyses were performed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA) and R version 4.3 (R Foundation for Statistical Computing, Vienna, Austria).

Results

Baseline characteristics

Among 353 treatment-naïve children and adolescents with primary hypertension assessed during the study period, 63 met the predefined echocardiographic criteria for LVR and were included as cases. The LVR phenotypes comprised eccentric hypertrophy in 50 participants, concentric hypertrophy in 9, and concentric remodeling in 4. Following 1:1 optimal matching without replacement, the final sample included 63 children with LVR and 63 with normal left ventricular geometry. The mean age was 13.00 ± 2.00 years in both groups, and each group included 54 boys (85.7%).

Matching was exact for age and sex. BMI was comparable between the LVR and normal-geometry groups (33.62 ± 5.34 vs. 33.28 ± 4.65 kg/m²; $P = 0.705$; SMD = 0.068). The absolute SMDs for weight, body surface area, waist circumference, hip circumference, and waist-to-height ratio were also < 0.10 . Residual imbalance was observed for height (absolute SMD = 0.146) and VAI (SMD = 0.364) (Supplementary Table S1).

Daytime systolic blood pressure exhibited higher values in the LVR group compared with the normal-geometry group (131.94 ± 9.11 vs. 129.18 ± 6.91 mmHg; $P = 0.046$). Between-group comparisons revealed no differences in 24 h or nighttime systolic blood pressure, 24 h, daytime, or nighttime diastolic blood pressure, or nocturnal dipping rates for systolic or diastolic measures. Grade 2 hypertension occurred more frequently in the LVR group (47.6% vs. 22.2%; $P = 0.005$), along with OSAS (81.0% vs. 57.1%; $P = 0.001$) and parental history of hypertension (52.4% vs. 30.2%; $P = 0.016$). Maternal history of gestational hypertension and metabolic syndrome showed no between-group difference. PDW was higher in the LVR group than in the normal-geometry group (12.22 ± 1.44 vs. 11.13 ± 1.18 fL; $P < 0.001$). MPV was also higher (10.44 ± 0.89 vs. 9.93 ± 0.78 fL; $P = 0.002$), whereas platelet count was lower (305.00 ± 85.96 vs. $332.29 \pm 56.76 \times 10^9/L$; $P = 0.027$) (Table 1). Triglyceride concentrations were numerically higher in the LVR group ($1.37 [1.11-1.90]$ vs. $1.23 [0.96-1.54]$ mmol/L; $P = 0.050$). Other laboratory characteristics are presented in Supplementary Table S2.

Table 1
Baseline ambulatory blood pressure, clinical, hematologic, and metabolic data for children grouped by left ventricular geometry (LVR vs normal).

	LVR group n = 63	Normal-geometry Group n = 63	<i>P</i> value
Ambulatory Blood Pressure (ABPM)			
24 h Mean SBP (mmHg)	128.51 ± 7.68	126.50 ± 6.23	0.086
24 h Mean DBP (mmHg)	75.00 (70.00–79.45)	73.00 (71.00–77.00)	0.173
Daytime SBP (mmHg)	131.94 ± 9.11	129.18 ± 6.91	0.046
Daytime DBP (mmHg)	77.80 (70.42–81.00)	76.00 (73.00–79.50)	0.693
Nighttime SBP (mmHg)	122.96 ± 8.12	122.05 ± 6.93	0.478
Nighttime DBP (mmHg)	71.93 ± 7.19	69.80 ± 6.48	0.063
SBP dipping rate (%)	6.64 ± 5.84	5.66 ± 4.10	0.224
DBP dipping rate (%)	6.25 ± 7.28	6.70 ± 5.58	0.674
Clinical Characteristics			
Hypertension grade, n(%)			0.005
Grade 1	33 (52.4%)	49 (77.8%)	
Grade 2	30 (47.6%)	14 (22.2%)	
Parental history of hypertension, n(%)	33 (52.4%)	19 (30.2%)	0.016
Maternal history of gestational hypertension, n(%)	7 (11.1%)	5 (7.9%)	0.774
OSAS, n(%)	51 (81.0%)	36 (57.1%)	0.001
Metabolic syndrome, n(%)	39 (61.9%)	43 (68.3%)	0.585
Key Hematologic and Inflammatory Markers			
WBC (×10 ⁹ /L)	7.58 ± 1.19	7.37 ± 1.27	0.389
PLT (×10 ⁹ /L)	305.00 ± 85.96	332.29 ± 56.76	0.027
MPV (fL)	10.44 ± 0.89	9.93 ± 0.78	0.002
PDW (fL)	12.22 ± 1.44	11.13 ± 1.18	< 0.001
ESR (mm/h)	10.35 ± 4.29	9.06 ± 4.47	0.079

	LVR group n = 63	Normal-geometry Group n = 63	<i>P</i> value
Ambulatory Blood Pressure (ABPM)			
Metabolic Profile			
Total cholesterol (mmol/L)	4.27 ± 0.92	4.05 ± 0.77	0.179
Triglycerides (mmol/L)	1.37 (1.11–1.90)	1.23 (0.96–1.54)	0.050
HDL-C (mmol/L)	1.05 ± 0.20	1.08 ± 0.22	0.470
LDL-C (mmol/L)	2.63 ± 0.70	2.51 ± 0.56	0.266
Uric acid (μmol/L)	489.88 ± 136.53	485.59 ± 90.64	0.816
Data are reported as mean ± SD, with median (IQR), or counts (percentages), where appropriate. To account for the matched design, paired t-tests or Wilcoxon signed-rank tests were applied to continuous variables, and McNemar tests for categorical noes. Baseline comparisons were descriptive and were not the sole criterion for covariate selection. Abbreviations: ABPM, ambulatory blood pressure monitoring; DBP, diastolic blood pressure; ESR, erythrocyte sedimentation rate; HDL-C, high-density lipoprotein cholesterol; IQR, interquartile range; LDL-C, low-density lipoprotein cholesterol; LVR, left ventricular remodeling; MPV, mean platelet volume; OSAS, obstructive sleep apnea syndrome; PDW, platelet distribution width; PLT, platelet count; SBP, systolic blood pressure; SD, standard deviation.			

Association of PDW with LVR and LVMI

In conditional logistic regression accounting for the matched design, each 1-fL increase in PDW was associated with greater odds of LVR in the unadjusted analysis (OR = 1.662; 95% CI, 1.231–2.244; *P* = 0.001). After adjustment for hypertension grade, OSAS, and VAI in Model 1, the association remained statistically significant (OR = 1.523; 95% CI, 1.105–2.100; *P* = 0.010). In Model 2, which additionally adjusted for ESR and parental history of hypertension, the association persisted (OR = 1.526; 95% CI, 1.094–2.129; *P* = 0.013) (Table 2).

Table 2
Conditional logistic regression modeling for LVR among matched pediatric patients with essential hypertension

Variable	Unadjusted OR (95% CI)	<i>P</i> value	Model 1 OR (95% CI)	<i>P</i> value	Model 2 OR (95% CI)	<i>P</i> value
PDW	1.66 (1.23–2.24)	0.001	1.52 (1.11–2.10)	0.010	1.53 (1.09–2.13)	0.013
OSAS	6.00 (1.77–20.37)	0.004	4.38 (1.06–18.11)	0.042	3.98 (0.94–16.80)	0.060
Hypertension grade	3.29 (1.41–7.66)	0.006	3.03 (1.14–8.02)	0.026	2.81 (0.99–7.98)	0.052
VAI	1.31 (0.99–1.75)	0.063	1.23 (0.88–1.71)	0.225	1.20 (0.86–1.69)	0.287
ESR	1.11 (1.01–1.22)	0.038	—	—	1.08 (0.98–1.20)	0.127
PHH	2.75 (1.22–6.18)	0.014	—	—	1.98 (0.78–5.01)	0.147
Conditional logistic regression was employed to handle the matched design, with normal left ventricular geometry serving as the reference outcome. ORs for PDW, VAI, and ESR are presented per 1-unit increment unless stated otherwise. Model 1 comprised PDW, hypertension grade, OSAS, and VAI. Model 2 additionally incorporated ESR and parental history of hypertension. Abbreviations: CI, confidence interval; ESR, erythrocyte sedimentation rate; LVR, left ventricular remodeling; OR, odds ratio; OSAS, obstructive sleep apnea syndrome; PDW, platelet distribution width; VAI, visceral adiposity index; PHH, Parental history of hypertension. For continuous measures, effect estimates are given per 1-fL increment in PDW and per 1-mm/h increase in ESR. Regarding hypertension grade, grade 1 served as the reference category, and effect estimate is reported for grade 2 relative to grade 1. Parental history of hypertension was treated as a binary variable.						

In linear regression, each 1-fL increase in PDW was associated with a 1.77-g/m^{2.16} increase in LVMI (β = 1.77; P = 0.002). LVMI also increased progressively across PDW quartiles (P for trend = 0.028) (Supplementary Figure S2).

Sensitivity and exploratory platelet-index analyses

Given the residual imbalance in VAI after matching, a sensitivity analysis was performed using the extended model without VAI. The association between PDW and LVR remained essentially unchanged

(OR = 1.520; 95% CI, 1.093–2.113; P = 0.013).

In exploratory analyses, MPV was associated with LVR when entered as the sole platelet index in a model adjusted for hypertension grade, OSAS, and VAI (OR = 1.865; 95% CI, 1.031–3.372; P = 0.039). However, when PDW and MPV were included simultaneously in the model, neither PDW (OR = 1.511; 95% CI, 0.887–2.574; P = 0.129) nor MPV (OR = 1.006; 95% CI, 0.375–2.702; P = 0.990) remained statistically significant. PDW had a numerically higher single-marker AUC than MPV (0.696 vs. 0.630), although the difference was not statistically significant (DeLong P = 0.092).

Discriminatory performance and incremental discrimination

As a single marker, PDW yielded an AUC of 0.696 (95% CI, 0.603–0.788) for discriminating between children with LVR and those with normal left ventricular geometry. The optimal cutoff identified using the Youden index was 11.5 fL, corresponding to a sensitivity of 0.698 and a specificity of 0.651 (Supplementary Figure S3 and Supplementary Table S3).

In the prespecified clinical model including hypertension grade, OSAS, and VAI, adding PDW increased the AUC from 0.703 to 0.791 (Δ AUC = 0.087; 95% CI, 0.022–0.152; DeLong P = 0.009). The corresponding IDI was 0.108 (95% CI, 0.008–0.276), and the continuous NRI was 0.603 (95% CI, 0.032–1.335).

In the extended model, which additionally included ESR and parental history of hypertension, adding PDW increased the AUC from 0.730 to 0.803 (Δ AUC = 0.074; 95% CI, 0.005–0.121; DeLong P = 0.013). The corresponding IDI was 0.099 (95% CI, 0.010–0.262). The continuous NRI was 0.667 (95% CI, – 0.192 to 1.302), with the confidence interval including zero (Table 3 and Fig. 1).

Table 3
Added predictive ability of PDW for LVR among matched pediatric subjects.

Model	AUC (base model)	AUC (+ PDW)	Δ AUC (95% CI)*	DeLong <i>P</i> value	IDI (95% CI)	Continuous NRI (95% CI)
Model 1	0.703	0.791	0.087 (0.022– 0.152)*	0.009	0.108 (0.008– 0.276)*	0.603 (0.032– 1.335)*
Model 2	0.730	0.803	0.074 (0.005– 0.121)*	0.013	0.099 (0.010– 0.262)*	0.667 (-0.192– 1.302)
Model 1 was the prespecified clinical model that included hypertension grade, OSAS, and VAI. Model 2 represented the extended model, which further incorporated ESR and parental history of hypertension. The area under the receiver operating characteristic curve (AUC) was used to assess discrimination. Improvements were evaluated using ΔAUC, integrated discrimination improvement (IDI), and continuous net reclassification improvement (NRI). Internal validation employed bootstrap resampling with 1000 replicates. * $P < 0.05$; Significance was concluded if the 95% confidence interval (CI) did not encompass 0. Abbreviations: AUC, area under the curve; IDI, integrated discrimination improvement; NRI, net reclassification improvement; PDW, platelet distribution width; OSAS, obstructive sleep apnea syndrome; ESR, erythrocyte sedimentation rate; VAI, visceral adiposity index						

Discussion

In this BMI-matched cohort of treatment-naïve children and adolescents with primary hypertension, higher PDW remained associated with LVR after adjustment for hypertension grade, OSAS, VAI, ESR, and parental history of hypertension. PDW was also positively associated with LVMI, which increased progressively across PDW quartiles. The PDW-LVR association remained essentially unchanged in the sensitivity analysis excluding VAI. In addition, adding PDW to the clinical models improved the AUC and IDI, although evidence for improvement in continuous reclassification was less consistent in the extended model because the confidence interval for the NRI included zero. Collectively, these findings suggest that PDW provides additional information regarding cardiac structural involvement beyond the selected clinical factors in this matched population.

Obesity is an important source of metabolic and inflammatory heterogeneity in pediatric primary hypertension. Adiposity is closely associated with blood pressure burden and abnormal left ventricular geometry, making it difficult to distinguish obesity-related influences from other factors associated with cardiac remodeling [3–5]. Previous pediatric studies have highlighted the contributions of obesity and systolic blood pressure burden to abnormal left ventricular geometry [4, 5], but statistical adjustment alone may leave residual confounding by body size, fat distribution, and metabolic status. The present

study therefore used 1:1 BMI matching to improve comparability with respect to overall adiposity at the design stage. VAI combines BMI, waist circumference, triglycerides, and high-density lipoprotein cholesterol ^[15] and has shown greater discriminatory ability than traditional adiposity indicators for unhealthy metabolic phenotypes among Chinese children and adolescents ^[16]. Because VAI remained imbalanced after matching, it was additionally included in the multivariable models. The similar estimate obtained after excluding VAI indicates that the PDW-LVR association was not dependent on the inclusion of VAI in the adjustment model. Nevertheless, neither BMI matching nor VAI adjustment can eliminate residual confounding related to body fat distribution or other unmeasured metabolic factors.

PDW reflects variability in platelet size. It has been described as a readily available indirect index related to platelet activation ^[17] and has been associated with P-selectin-dependent platelet function ^[6]. Pediatric primary hypertension involves interacting hemodynamic, metabolic, inflammatory, endothelial, and neurohumoral processes ^[3, 18], whereas circulating platelets participate in immune, inflammatory, and thrombotic signaling ^[19]. One possible interpretation is that PDW and cardiac remodeling represent parallel indicators of a shared systemic pathophysiological burden. These processes may also be considered within the broader conceptual framework of early vascular aging (EVA) ^[20, 21]. However, this interpretation remains hypothetical. Because the present study did not measure platelet function, endothelial function, arterial stiffness, or other vascular aging phenotypes, the findings should not be interpreted as evidence of platelet activation, a platelet-driven mechanism of myocardial remodeling, or EVA.

Our findings are broadly consistent with, but also add nuance to, previous adult studies. In a cohort of 1,241 cardiology patients, Fujita et al. reported that PDW and other platelet volume indices were independently associated with left ventricular hypertrophy and systolic and diastolic cardiac dysfunction ^[7]. In adults with metabolic syndrome, Li et al. found that PDW was positively correlated with LVMI and independently associated with left ventricular hypertrophy and other forms of organ damage ^[8]. Adult evidence regarding platelet indices and cardiac remodeling has not been entirely consistent: Yavuzkir et al. found higher MPV in untreated hypertensive adults but no significant correlation between MPV and LVMI ^[22]. Higher PDW has also been associated with adverse prognosis in chronic heart failure ^[23], although that clinical setting and endpoint differ substantially from pediatric cardiac remodeling. Pediatric evidence remains limited. In 125 untreated children with primary hypertension, Sun et al. found higher PDW among children with a non-dipping blood pressure pattern, while left ventricular hypertrophy was more frequent in the non-dipping group ^[9]. However, that study did not directly evaluate whether PDW was independently associated with abnormal left ventricular geometry. The present study extends the pediatric evidence by demonstrating associations of PDW with both LVR and continuous LVMI in a BMI-matched hypertensive cohort.

Grade 2 hypertension and OSAS were more prevalent among children with LVR. These findings are consistent with pediatric evidence relating greater systolic blood pressure burden to hypertrophic cardiac remodeling ^[5] and relating OSAS to increased LVMI, left ventricular hypertrophy, and abnormal

left ventricular geometry^[24–27]. Importantly, PDW remained associated with LVR after adjustment for hypertension grade, OSAS, and additional clinical variables, suggesting that the association was not explained solely by hypertension severity or coexisting sleep-disordered breathing. MPV was also higher in children with LVR and was associated with LVR when assessed separately in an exploratory adjusted model. However, simultaneous inclusion of PDW and MPV attenuated both associations. Although PDW had a numerically higher single-marker AUC than MPV, the difference was not statistically significant. These exploratory findings suggest that PDW and MPV may capture overlapping platelet morphological information, but the present data do not establish the superiority of either marker.

PDW is routinely reported as part of a complete blood count and generally does not require an additional laboratory assay^[6, 9]. Nevertheless, its modest single-marker AUC does not support its use as a stand-alone screening marker. The increases in AUC and IDI after adding PDW indicate improved in-sample discrimination beyond the selected clinical factors. However, because discrimination was evaluated in the same sample used for model estimation, these findings do not establish a validated prediction tool, a clinical decision threshold, or a criterion for echocardiographic referral. PDW may instead warrant further evaluation as an adjunctive hematologic signal in children with primary hypertension. Its clinical usefulness requires confirmation in prospective cohorts with external validation.

Study limitations

Several limitations should be acknowledged. First, the retrospective, single-center, matched case-control design precludes conclusions regarding temporal sequence or causality and is susceptible to selection bias. In particular, the duration of clinically unrecognized hypertension before diagnosis could not be determined, and inclusion depended on the availability of complete echocardiographic and clinical data. Second, the sample of 63 matched pairs limited statistical precision and the ability to examine individual LVR phenotypes. Third, PDW was measured at a single time point and may be influenced by analyzer-specific and pre-analytical factors; direct platelet-function measures, such as P-selectin expression or platelet-leukocyte aggregates, were unavailable. Fourth, although BMI matching and VAI adjustment reduced adiposity-related confounding, residual confounding by body-fat distribution, metabolic status, and other unmeasured factors cannot be excluded; VAI is also an indirect index rather than a direct measure of visceral fat. Fifth, the MPV analyses were exploratory, and attenuation of both PDW and MPV in the joint model limits conclusions regarding their relative value. Finally, discrimination was evaluated in the same cohort used for model estimation. The modest single-marker AUC, the less consistent continuous NRI in the extended model, and the absence of external validation indicate that the discriminatory findings remain preliminary. Model calibration, absolute-risk estimation, clinical decision thresholds, and net clinical benefit could not be assessed. Prospective multicenter studies with external validation and adequate representation of different LVR phenotypes are therefore warranted.

Conclusions

In conclusion, higher PDW was associated with LVR and higher LVMI in BMI-matched, treatment-naive children and adolescents with primary hypertension. The in-sample improvement in discrimination after adding PDW suggests potential incremental information beyond the selected clinical factors, but it does not establish a clinically deployable prediction tool. Despite the study's limitations, the concordant associations of PDW with LVR and LVMI support continued investigation of platelet heterogeneity in relation to early cardiac structural involvement in pediatric hypertension.

Abbreviations

Abbreviation	Full Term
LVH	Left ventricular hypertrophy
PDW	Platelet distribution width
LVMI	Left ventricular mass index
PH	Primary hypertension
ROC	Receiver-operating characteristic
OSAS	Obstructive sleep apnea syndrome
OAHI	Obstructive apnea–hypopnea index
NLR	Neutrophil-to-lymphocyte ratio
MPV	Mean platelet volume
MCHC	Mean corpuscular hemoglobin concentration
BMI	Body mass index
VAI	Visceral adiposity index
RDW	Red cell distribution width
ESR	Erythrocyte sedimentation rate
HOMA-IR	Homeostasis model assessment of insulin resistance
ABPM	Ambulatory blood pressure monitoring
NRI	Net reclassification improvement
IDI	Integrated discrimination improvement
AUC	Area under the receiver-operating characteristic curve

Declarations

Ethics approval and consent to participate

The study was approved by the Medical Ethics Committee of Beijing Children's Hospital, Capital Medical University (approval no. [2024]-Y-112-D). The requirement for informed consent to participate was waived by the committee because of the retrospective study design. All data were anonymized before analysis, and the study was conducted in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable.

Availability of data and materials

The data underlying this article are not publicly available due to privacy and ethical restrictions.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Conceptualization: KZ and NM. Data curation: KZ. Formal analysis: KZ, RS, HZ, JY, GL, LX, JL, SL, YD, and ZO. Funding acquisition: NM. Investigation: KZ, RS, YS, HZ, JY, GL, LX, JL, SL, YD, ZO, and NM. Methodology: KZ, RS, JY, GL, LX, YS, HZ, JL, SL, YD, and ZO. Project administration: KZ and NM. Supervision: NM. Validation: KZ. Writing - original draft: KZ. Writing - review and editing: KZ, RS, JY, GL, LX, YS, HZ, JL, SL, YD, ZO, and NM. All authors read and approved the final manuscript.

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Use of generative AI

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) solely for English-language editing and improving the clarity and readability of the text. The tool was not used for study design, data collection, statistical analysis, interpretation of the results, or generation of scientific conclusions. All AI-assisted text was critically reviewed and revised by the authors, who take full responsibility for the accuracy, integrity, and final content of the manuscript.

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Figures

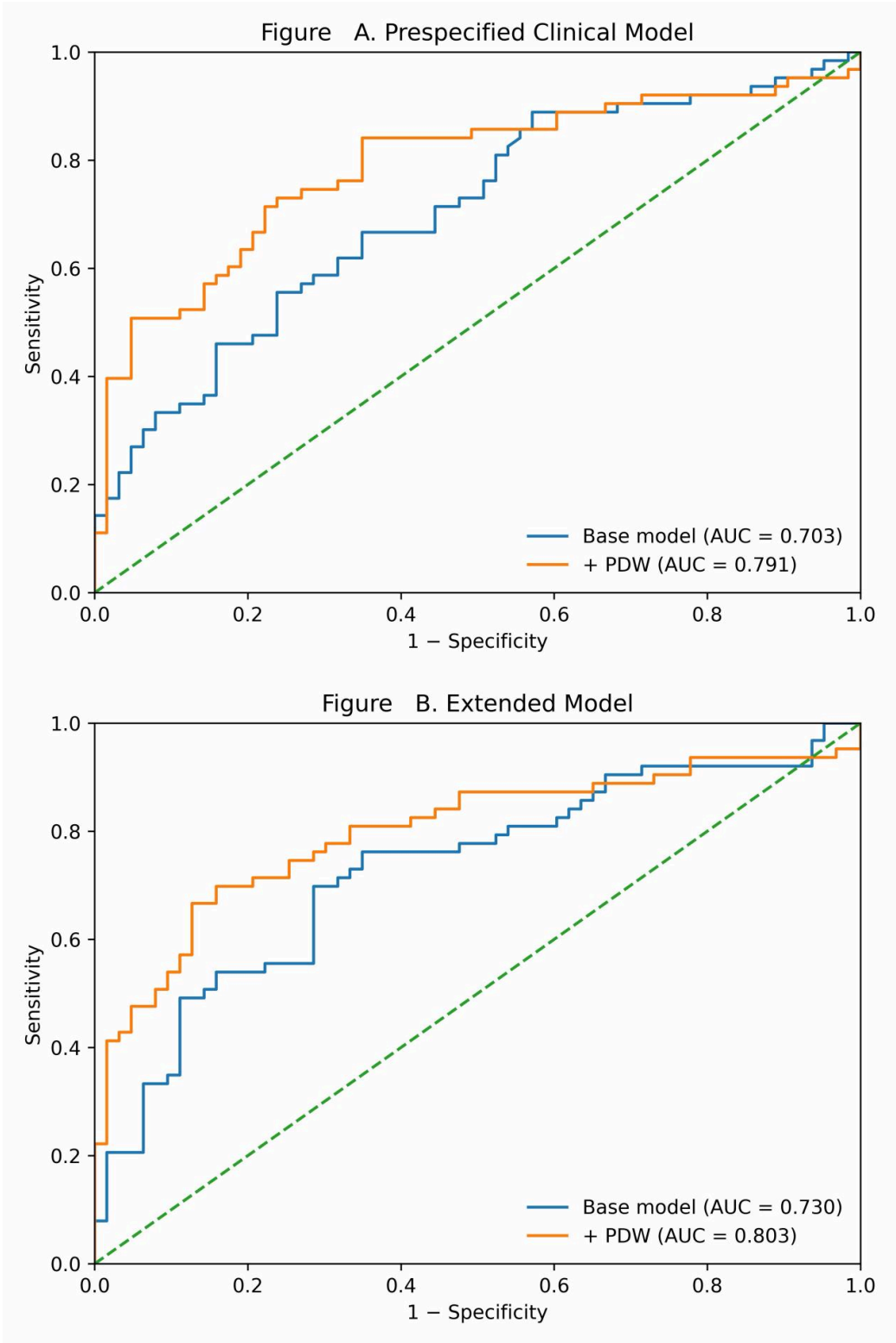


Figure 1

Incremental discriminatory value of platelet distribution width (PDW) for predicting left ventricular remodeling (LVR).

Receiver operating characteristic curves for the prespecified clinical model (A) and the extended model (B), before and after adding PDW. The prespecified model included hypertension grade, OSAS, and VAI; the extended model additionally included ESR and parental history of hypertension.

AUC, area under the receiver operating characteristic curve; ESR, erythrocyte sedimentation rate; OSAS, obstructive sleep apnea syndrome; PDW, platelet distribution width; VAI, visceral adiposity index.

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