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Re-evaluating cardiovascular risk in systolic-dominant, diastolic-dominant and parallelly-elevated hypertension: insights from northeast rural cardiovascular health study

Qiyu Li[1], Pengbo Wang[1], Yingxian Sun[1], Yanli Chen[1,2]✉ & Xingang Zhang[1,2]✉

Background Hypertension is a major risk factor for cardiovascular disease (CVD), with a high prevalence in rural northeastern China. This study assesses the cardiovascular risk associated with different blood pressure patterns: systolic dominant, diastolic dominant, and parallel elevation.
Methods We analyzed data from the Northeast Rural Cardiovascular Health Study (NCRCHS), which included 8,189 participants aged 35 and above. Baseline surveys from 2012 to 2013 and follow-ups in 2015 and 2018 provided a median follow-up of 4.66 years. Participants were categorized into ten subgroups based on systolic and diastolic blood pressure elevations. Kaplan-Meier curves and Cox regression models were used to examine CVD incidence and cardiovascular risk across these groups.
Results The incidence of CVD varied significantly among hypertension categories. Patients with grade 1 hypertension had no significant increase in cardiovascular risk at nearly 5 years. Notably, parallel elevations in systolic and diastolic pressures posed the highest cardiovascular risk, while a predominant rise in diastolic pressure alone did not significantly increase risk. This highlights the importance of analyzing blood pressure comprehensively for cardiovascular risk stratification and suggests rethinking treatment strategies for diastolic dominant hypertension.
Conclusions Our findings call for a nuanced approach to cardiovascular risk assessment in hypertension, taking into account distinct patterns of systolic and diastolic blood pressure. The study supports personalized treatment interventions and reinforces current hypertension treatment guidelines. We advocate for prioritizing non-pharmacological management in grade 1 hypertension and further clinical evaluation of treatment thresholds for diastolic dominant hypertension.

Keywords Hypertension, Cardiovascular risk, Systolic blood pressure, Diastolic blood pressure, Cohort study, Northeast Rural Cardiovascular Health Study

Cardiovascular disease (CVD) is the foremost chronic illness globally[1] and a primary cause of morbidity and mortality[2,3], imposing significant economic and healthcare burdens[4,5]. Hypertension, a prevalent chronic condition characterized by elevated blood vessel pressure, is widely recognized as a primary risk factor for CVD[6,7]. More than a third of the global population suffers from hypertension, placing them at an increased risk of CVD[8]. Blood pressure measurement is a routine part of clinical assessment, providing essential data for cardiovascular risk stratification based on the World Health Organization's classifications[9,10]. However, recent research suggests that hypertension does not always present with parallel increases in systolic and diastolic blood pressure, leading to interest in systolic dominant hypertension and diastolic dominant hypertension. Traditional categorization often overlooks the nuanced differences between these presentations, potentially misrepresenting their associated cardiovascular risks. This classification ambiguity poses challenges in clinical decision-making, as it obscures the relationship between specific hypertension profiles and their associated risks.

[1]Department of Cardiology, The First Hospital of China Medical University, 155 Nanjing North Street, Heping District, 110001 Shenyang, Liaoning Province, People's Republic of China. [2]Yanli Chen and Xingang Zhang contributed equally to the manuscript. ✉email: ylchen@cmu.edu.cn; zhangxingang80@aliyun.com

Take, for instance, two distinct blood pressure readings of 180/90 mmHg and 140/110 mmHg; both are categorized as grade 3 hypertension, yet they present differently. The question arises whether their cardiovascular risks are equivalent and whether they warrant identical management approaches. Contemporary blood pressure classification schemes have yet to clarify these issues, which are frequently faced in clinical practice. Thus, there is a pressing need for refined categorization methods to better guide clinicians in managing diverse hypertension presentations and associated risks.

Our study introduces a refined blood pressure grading system to distinguish between systolic dominant, diastolic dominant, and parallelly elevated hypertension, aiming to clarify the cardiovascular risk associated with each pattern.

Method

Study population

The study cohort was derived from the Northeast Rural Cardiovascular Health Study (NCRCHS), established in Liaoning Province between January 2012 and August 2013. This cohort included 11,956 residents aged 35 years or older. Detailed methodologies have been previously described[11,12]. Briefly, a multi-stage, random cluster sampling method was employed to select subjects from 26 villages across three counties within the province. All residents aged 35 and above were invited to participate, with those completing the baseline survey ultimately included in the study. Baseline data collection consisted of face-to-face interviews, physical examinations, and blood biochemical analyses. Follow-ups conducted in 2015 and 2018 assessed cardiovascular event incidence, with a median follow-up duration of 4.66 years.

From the initial population, we excluded 887 individuals with a history of CVD and 1,426 who had taken anti-hypertensive medication within the two weeks preceding the study. An additional 1,454 participants were excluded at the 2018 follow-up due to incomplete data or absence at follow-up appointments. Consequently, 8,189 subjects were included in the final analysis. The Ethics Committee of China Medical University approved the study protocol, all methods were performed in accordance with the relevant guidelines and written informed consent was obtained from all participants. The detailed subject selection process is shown in Fig. 1.

Study variables and definitions

T Participant demographics, including age, sex, ethnicity, smoking and drinking status, regular exercise habits (≥ 3 times/week), and family history of hypertension (HTN), coronary heart disease (CHD), and stroke, were collected via face-to-face interviews. Blood pressure (BP) measurements were taken in a controlled environment with a moderate temperature (approximately 23 degrees Celsius). Participants rested for at least five minutes before measurements, with their bare upper arm positioned at heart level. Trained staff took BP readings using a standard electronic sphygmomanometer (HEM-907; Omron, Tokyo, Japan), with three measurements at two-minute intervals and the average recorded. Body weight and waist circumference (WC) were measured under standardized conditions, and blood samples were collected after a minimum 12-hour fast for biochemical

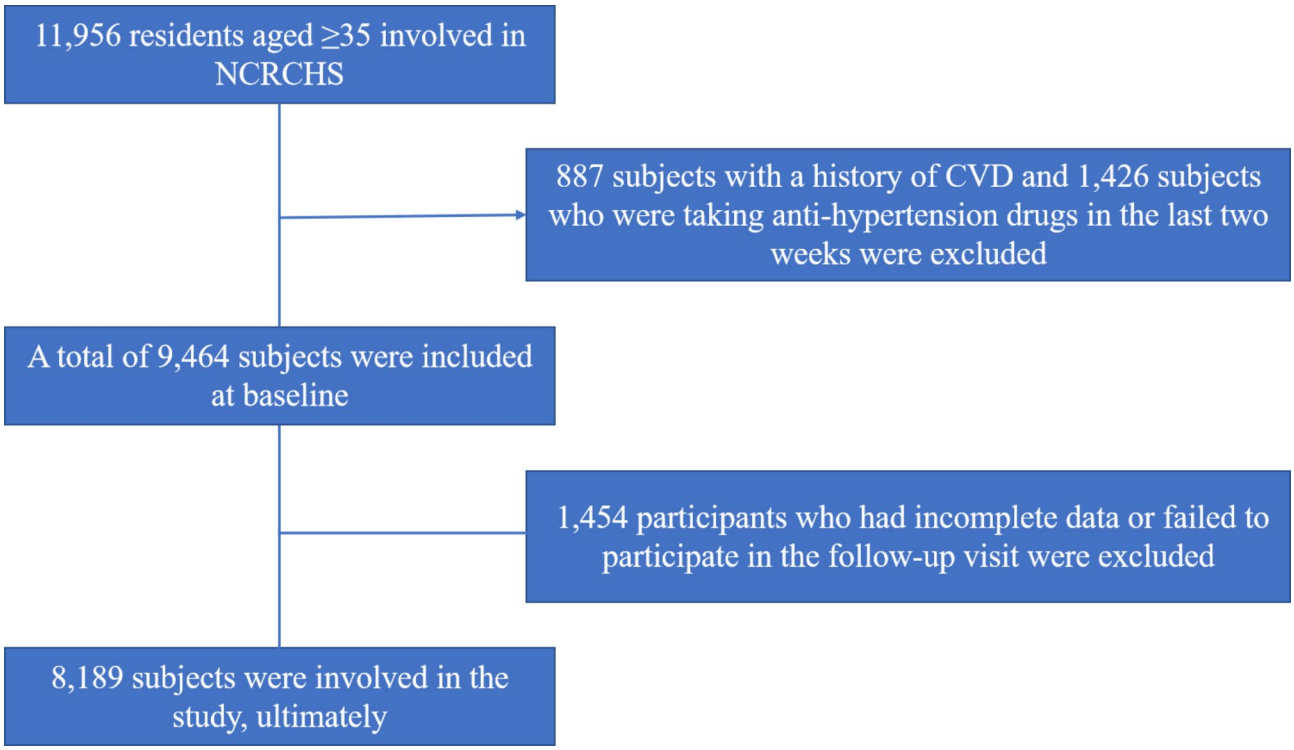

Fig. 1. Flow chart of subject screening.

analysis. Parameters analyzed included triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), fasting plasma glucose (FPG), serum creatinine (Scr), and uric acid (UA). The estimated glomerular filtration rate (eGFR) was calculated using the CKD-EPI equation[13], and body mass index (BMI) was computed as weight in kilograms divided by height in meters squared.

The primary endpoint was the incidence of CVD, including fatal and non-fatal stroke and CHD[14]. CHD was defined as a diagnosis of hospitalized angina, myocardial infarction, undergoing revascularization, or death from coronary artery related disease[15]. Stroke was defined as rapidly developing brain dysfunction caused by cerebrovascular factors and lasting more than 24 h (unless interrupted by surgery or death) according to the World Health Organization Multinational Monitoring of Trends and Determinants in Cardiovascular Disease criteria[16,17]. We gathered comprehensive clinical data during follow-ups, and an Endpoint Evaluation Committee independently reviewed and adjudicated all cases.

Stratification of the blood pressure

Blood pressure categories were assigned according to WHO hypertension guidelines[10]: non-hypertensive ($BP < 140/90$ mmHg), Grade 1 hypertension ($140/90 \leq BP < 160/100$ mmHg), Grade 2 hypertension ($160/100 \leq BP < 180/110$ mmHg), and Grade 3 hypertension ($BP \geq 180/110$ mmHg). In instances of discrepant systolic and diastolic BP classifications, the higher category prevailed.

For refined hypertension stratification, we identified patterns as systolic dominant (S1: $140 \leq SBP < 160$ and $DBP < 90$; S2: $160 \leq SBP < 180$ and $DBP < 100$; S3: $SBP \geq 180$ and $DBP < 110$), diastolic dominant (D1: $90 \leq DBP < 100$ and $SBP < 140$; D2: $100 \leq DBP < 110$ and $SBP < 160$; D3: $DBP \geq 110$ and $SBP < 180$), or parallelly elevates (S1D1, S2D2, S3D3 for corresponding systolic and diastolic ranges). The detailed schematic diagram of blood pressure grading method is shown in Fig. 2.

Statistical analysis

Descriptive statistics for variables were computed, with continuous variables presented as mean ± standard deviation, and categorical variables as frequencies (percentages). Group differences were evaluated using nonparametric and chi-squared tests. Blood pressure subgroup distributions and incidence rates were visualized using pie and bar charts, respectively. Kaplan-Meier curves illustrated CVD incidence, with P-values assessing intergroup differences. Cox regression determined hazard ratios (HRs) and 95% confidence intervals (CIs), adjusted for collinearity with a variance inflation factor (VIF) < 10. Data analyses were performed using IBM SPSS Statistics software, version 26, with a two-tailed P-value of < 0.05 considered statistically significant.

Results

Baseline characteristics of the study population

Among the 8,189 participants, the average age was 52.4 years, with males comprising 47.9%. Throughout the median follow-up duration of 4.66 years, 339 participants were diagnosed with cardiovascular disease (CVD), representing an incidence rate of 4.14%. Hypertensive patients constituted 41.9% of the cohort, with systolic dominant hypertension, diastolic dominant hypertension, and parallelly elevated hypertension accounting for 69.1%, 8.2%, and 22.6% of the hypertensive subset, respectively.

Hypertensive individuals were generally older and had a higher prevalence of male gender, familial hypertension history, smoking, and alcohol consumption compared to their non-hypertensive counterparts. These individuals also presented with elevated BMI, WC, FPG, LDL-C, and UA, alongside reduced eGFR. Notably, patients with systolic dominant hypertension were, on average, older and had lower proportions of males, smokers, and alcohol users, with decreased BMI, WC, eGFR, and UA levels than those with other hypertension types. They were also more likely to maintain regular exercise routines. In contrast, diastolic dominant hypertension was more common in younger individuals, predominantly males, with fewer reporting a family history of CHD and stroke. This group did, however, exhibit higher smoking and alcohol consumption rates and significantly elevated UA levels compared to the other groups, as detailed in Table 1.

Blood pressure distributions across hypertension grades

Blood pressure classification was refined for all participants according to varying degrees of systolic and diastolic increases, with the cohort segmented into ten groups (refer to Methods for detailed criteria). A pie chart was

SBP \ DBP	<90	90-100	100-110	≥110
<140	N	S0D1	S0D2	S0D3
140-160	S1D0	S1D1	S1D2	S1D3
160-180	S2D0	S2D1	S2D2	S2D3
≥180	S3D0	S3D1	S3D2	S3D3

N:non-hypertension
G1:Grade 1 hypertension
G2:Grade 2 hypertension
G3:Grade 3 hypertension

Fig. 2. Schematic diagram of blood pressure grades.

	non-HTN	systolic dominant HTN	diastolic dominant HTN	parallelly elevated HTN		Total
	n = 4756(58.1%)	*n* = 2375(29.0%)	*n* = 282(3.4%)	*n* = 778(9.5%)	*p*-value	*n* = 778(9.5%)
age(year)	49.9 ± 9.4	57.7 ± 10.3	50.1 ± 8.8	52.0 ± 8.5	<0.001	52.4 ± 10.2
male(%)	2074(43.6)	1217(51.2)	171(60.6)	463(59.5)	<0.001	3925(47.9)
ethnicity of Han(%)	4491(94.5)	2222(93.6)	270(95.7)	724(93.1)	0.209	7707(94.1)
family history of HTN(%)	937(19.7)	491(20.7)	63(22.3)	182(23.4)	0.009	1673(20.4)
family history of CHD(%)	654(13.8)	292(12.3)	35(12.4)	105(13.5)	0.335	1089(13.3)
family history of Stroke(%)	694(14.6)	400(16.8)	39(13.8)	122(15.7)	0.081	1255(15.3)
current smoking(%)	1698(35.7)	917(38.6)	116(41.1)	304(39.1)	0.023	3035(37.1)
current drinking(%)	988(20.8)	667(28.1)	106(37.6)	286(36.8)	<0.001	2047(25.0)
regular exercise(%)	823(17.3)	522(22.0)	56(19.9)	162(20.8)	<0.001	1563(19.1)
BMI(kg/m^2)	24.0 ± 3.6	25.0 ± 3.4	25.4 ± 3.8	25.6 ± 3.7	<0.001	24.5 ± 3.6
WC(cm)	79.6 ± 9.2	83.5 ± 9.4	84.6 ± 10.1	84.6 ± 9.6	<0.001	81.4 ± 9.6
SBP(mmHg)	124.1 ± 9.7	159.0 ± 16.8	144.2 ± 13.5	156.8 ± 16.4	<0.001	138.0 ± 21.1
DBP(mmHg)	75.1 ± 7.3	84.3 ± 8.9	98.5 ± 7.7	96.9 ± 7.6	<0.001	80.6 ± 10.9
FPG(mmol/L)	5.6 ± 1.2	6.1 ± 1.9	6.1 ± 2.2	5.9 ± 1.2	<0.001	5.8 ± 1.5
TC(mmol/L)	5.0 ± 1.0	5.4 ± 1.0	5.5 ± 1.1	5.4 ± 1.1	<0.001	5.2 ± 1.1
TG(mmol/L)	1.4 ± 1.2	1.6 ± 1.5	2.0 ± 2.0	1.8 ± 2.1	<0.001	1.5 ± 1.4
HDL-C(mmol/L)	1.4 ± 0.4	1.5 ± 0.4	1.4 ± 0.4	1.4 ± 0.4	<0.001	1.4 ± 0.4
LDL-C(mmol/L)	2.8 ± 0.8	3.1 ± 0.8	3.0 ± 0.8	3.0 ± 0.8	<0.001	2.9 ± 0.8
eGFR($ml/min/1.73m^2$)	96.3 ± 13.8	93.3 ± 14.7	95.9 ± 21.0	94.8 ± 13.6	<0.001	95.2 ± 14.4
UA(μmmol/L)	278.2 ± 78.6	284.7 ± 80.2	325.5 ± 99.0	306.6 ± 83.8	<0.001	284.4 ± 81.1

Table 1. Baseline character of study population. Abbreviations: HTN: hypertension; CHD: coronary heart disease; BMI: body mass index; WC: waist circumference; SBP: systolic blood pressure; DBP: diastolic blood pressure; FPG: fasting plasma glucose; TC: total cholesterol; TG: triglyceride; HDL-C: high density lipoprotein cholesterol; LDL-C: low density lipoprotein cholesterol; eGFR: estimated glomerular filtration rate; UA: uric acid.

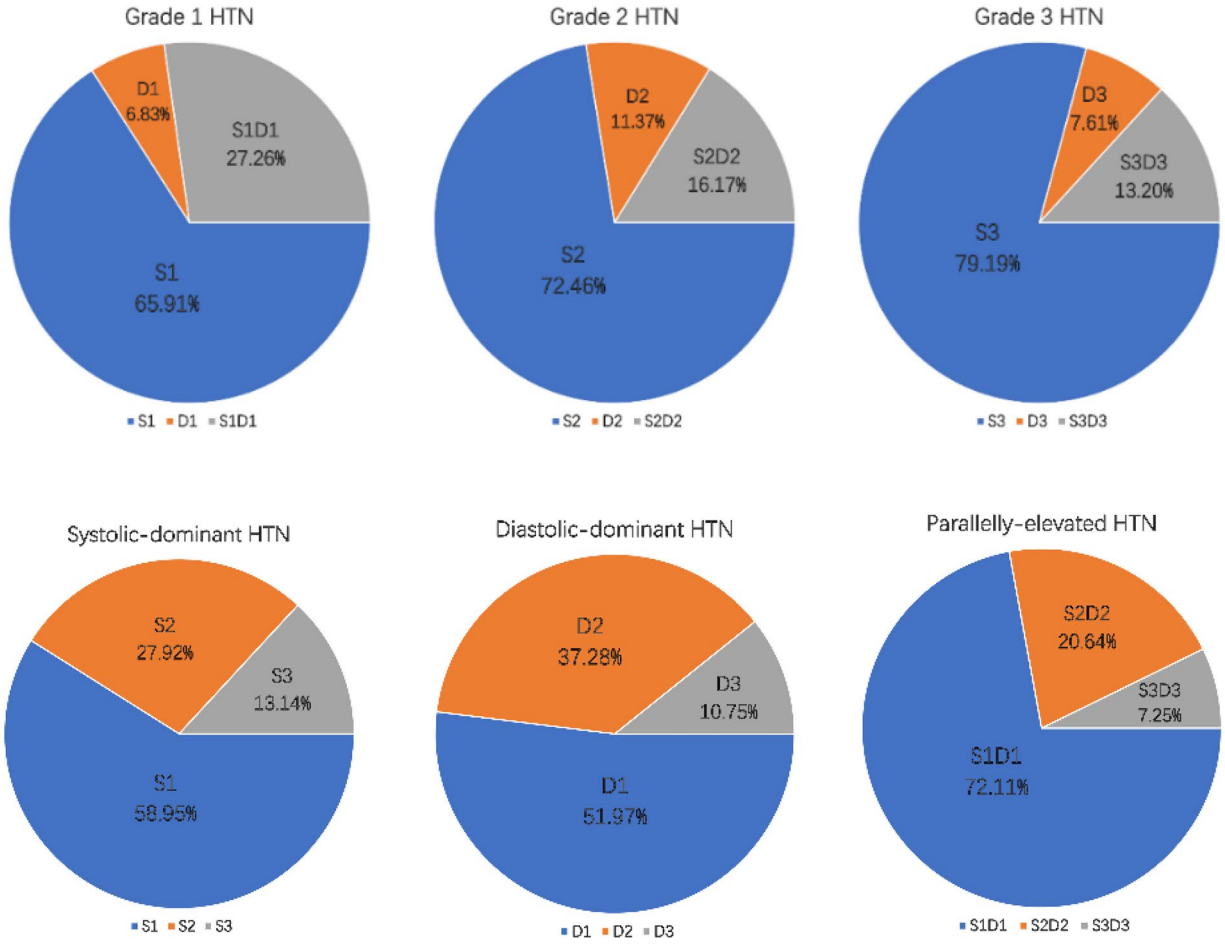

Fig. 3. Pie chart illustrating the distribution proportion of each subgroup.

constructed to depict the distribution of each subgroup within different hypertension categories as detailed in Fig. 3. Results showed that within Grade 1, 2, and 3 hypertensive patients, those with systolic dominant hypertension formed the majority, at 65.91%, 72.46%, and 79.19%, respectively. Patients with parallelly elevated systolic and diastolic pressures constituted the second-largest group at 27.16%, 16.16%, and 13.20%, respectively, while diastolic dominant hypertension was least common at 6.83%, 11.37%, and 7.61%, respectively. An increase in systolic dominant hypertension was observed with rising hypertension severity, conversely, the prevalence of parallelly elevated hypertension declined.

When categorized according to systolic-dominant hypertension, diastolic-dominant hypertension, and parallelly-elevated hypertension, it can be seen that the proportion of patients with Grade 1 hypertension is the highest, accounting for 58.95%, 51.97%, and 72.11% respectively; the proportion with Grade 2 hypertension follows, at 27.92%, 37.28%, and 20.64% respectively; and the proportion with Grade 3 hypertension is the smallest, at 13.14%, 10.75%, and 7.25% respectively.

Incidence of CVD across subgroups

Histograms illustrating the incidence of CVD across varying blood pressure levels were generated, as depicted in Fig. 4. The lowest incidence was observed in the non-hypertensive population, at 5.8 per 1,000 person-years. Among individuals with Grade 1, 2, and 3 hypertension, the incidence rates progressively increased. For Grade 1 hypertension, the incidences were similar among the S1, D1, and S1D1 subgroups, at 10.9, 9.4, and 10.7 per 1,000 person-years, respectively. For Grades 2 and 3, incidence disparities among subgroups were more pronounced. The S2D2 and S3D3 groups had incidences of 23.8 and 45.2 per 1,000 person-years, respectively, surpassing those of the S2 and S3 groups, which stood at 18.8 and 32.0 per 1,000 person-years. The D2 and D3 groups, however, exhibited significantly lower incidences of 11.4 and 14.3 per 1,000 person-years, relative to their systolic-dominant and parallelly-elevated hypertension counterparts within the same grade.

Kaplan-Meier curve and cumulative survival risk

Survival analysis utilized Kaplan-Meier (K-M) curves, as depicted in Fig. 5, to illustrate the cumulative risk of cardiovascular events among patients. Initially, individuals were categorized into four distinct groups based

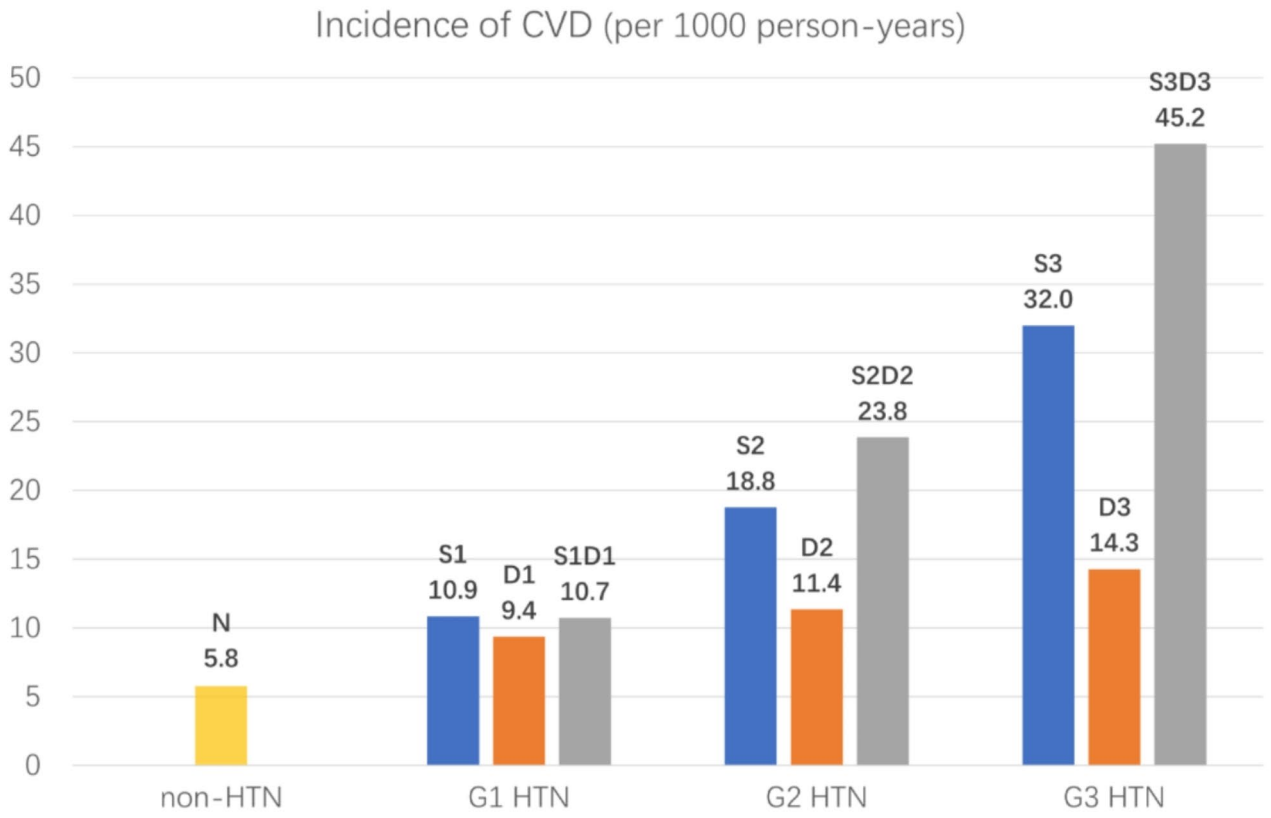

Fig. 4. Incidence of CVD.

on blood pressure status: normotensive, systolic-dominant hypertension, diastolic-dominant hypertension, and combined systolic and diastolic hypertension. K-M curve were subsequently generated as detailed in Fig. 5.B. The analysis revealed a gradation in the risk of cardiovascular events across different types of hypertension, with the most pronounced risk observed in patients with systolic-dominant and parallelly-elevated hypertension. In contrast, those with diastolic-dominant hypertension manifested a comparatively moderate increase in blood pressure.

Refinement of blood pressure categories led to the generation of additional K-M curves, detailed in Fig. 5.B, C, D, and E. Figure 5.B shows that the S3D3 group encountered the highest cumulative risk, followed sequentially by the S3 group, S2D2 and S2 groups. The intergroup differences were statistically significant, as indicated by a log-rank p-value of less than 0.001. Further K-M analyses for Grades 1, 2, and 3 hypertension, presented in Fig. 5.C, D, and E, respectively, reveal nuanced results. In Grade 1 hypertension, the risk of cardiovascular disease incidence in the S1, D1, and S1D1 subgroups was marginally elevated compared to the normotensive group (N). For Grades 2 and 3 hypertension, each subgroup exhibited a more marked increase in risk, with the S2D2 and S3D3 subgroups showing the most substantial elevation. The S2 and S3 subgroups experienced a slightly lower but still significant risk, and the D2 and D3 subgroups had the smallest increase in risk. Notably, the differences between these groups were statistically significant, with log-rank p-values < 0.001 across the board.

Cardiovascular risk assessment via cox regression

Data on the population size of each subgroup and the corresponding number of cardiovascular events were tabulated in Table 2, along with the outcomes of Cox regression analyses, inclusive of HRs and 95% CIs. The model was adjusted for potential confounders, including age, sex, ethnicity, smoking status, alcohol intake, physical activity levels, and family history of CHD and stroke, as well as BMI, LDL-C, FPG, eGFR, and UA. No statistically significant elevation in CVD risk was detected in the Grade 1 hypertension cohort (encompassing S1, D1, and S1D1), nor in the D2 and D3 categories, as opposed to the non-hypertensive group. Contrastingly, the S2 group presented a 60% heightened risk (HR: 1.596; 95% CI: 1.135–2.246), which escalated to 214% in the S2D2 group (HR: 3.136; 95% CI: 1.811–5.430), and 138% in the S3 group (HR: 2.375; 95% CI: 1.625–3.471); the S3D3 group faced an increase of 516% (HR: 6.164; 95% CI: 3.108–12.227).

Furthermore, we observed that participants in the S2D2 group and the S3 subgroup were classified into stage 2 and stage 3 hypertension, respectively, according to the current blood pressure categorization criteria. However, the cardiovascular risk for the S2D2 group was 3.136 times greater than that of the normotensive group, while the S3 group had a risk that was 2.375 times higher than the normotensive group. Consequently, we conducted a post-hoc analysis comparing the cardiovascular risk between the S2D2 group and the S3 group. The

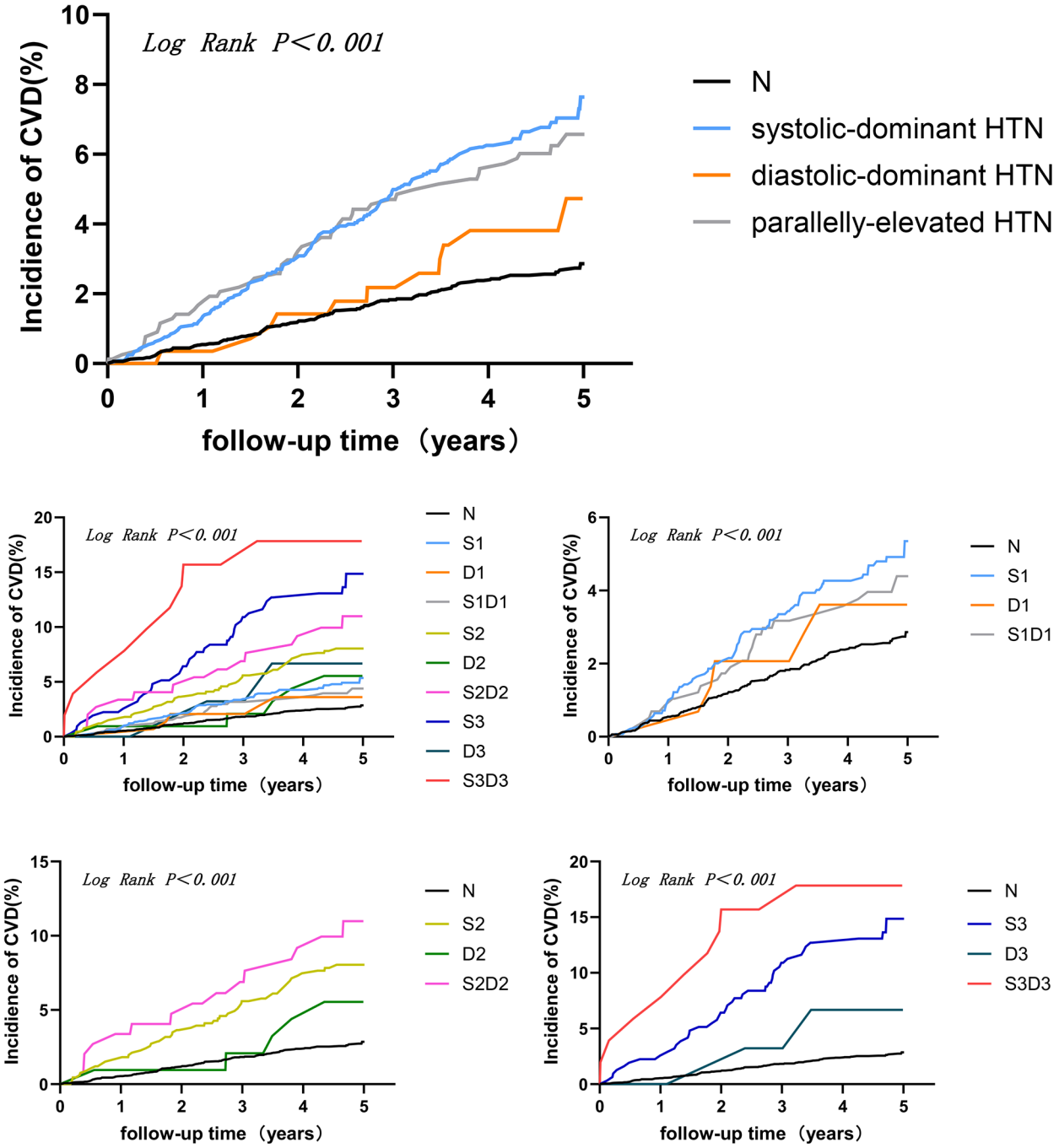

Fig. 5. Kaplan-Meier curves.

results indicated a HR of 1.165, with a 95% CI of 0.601–2.258 and a P-value of 0.651, suggesting no statistically significant difference between the groups, indicating no increase or decrease in risk between the S2D2 and S3 groups. The result suggests that the risk of CVD was slightly higher in the S2D2 group than in the S3 group compared to the non-hypertensive group, but when comparing the two groups, the risk was almost identical in the S2D2 and S3 groups.

Subgroup analysis

Subgroup analyses employing Cox regression were conducted anew, predicated on gender and age criteria. These findings, as demonstrated in Table 3, slightly diverged from those observed in the aggregate population, with augmented cardiovascular risk observed in the S1D1 male subgroup. Among female participants, no notable risk upsurge was discerned in the S2 and S3 subgroups, nor was there a significant increase in the S2 cohort

	Incidence *N*	Total *N*	HR	95%CI	*P*
N	119	4758	-	-	-
S1	65	1400	1.176	0.861–1.606	**0.309**
D1	6	145	1.592	0.699–3.628	**0.268**
S1D1	27	579	1.363	0.868–2.140	**0.179**
S2	53	663	1.596	1.135–2.246	0.007
D2	5	104	1.590	0.646–3.915	**0.313**
S2D2	15	148	3.136	1.811–5.430	<0.001
S3	41	312	2.375	1.625–3.471	<0.001
D3	2	30	2.446	0.601–9.952	**0.212**
S3D3	10	52	6.164	3.108–12.227	<0.001

Table 2. Cox analysis with adjustment for multiple confounders.

among individuals aged above 55 years. Notwithstanding, across both gender and age, the risk in the D2 and D3 subgroups did not significantly exceed that of the normotensive cohort (N).

Discussion

This cohort study, conducted in a rural region of northeastern China—a locale with a notably high prevalence of hypertension and cardiovascular diseases[18,19] —explores the association between different patterns of blood pressure elevation and cardiovascular risk. Our innovative approach reclassified participants into nuanced blood pressure categories based on SBP and DBP levels, yielding insights into cardiovascular risk stratification. The data suggest that for individuals with Grade 1 hypertension, cardiovascular risk do not increase in the follow-up time of nearly 5 years, while for individuals with Grade 2 or higher hypertension, cardiovascular risk escalates in tandem with the magnitude of SBP elevation and parallel increases in SBP and DBP. On the other hand, diastolic dominant hypertension did not correlate with a significant uptick in cardiovascular risk, a finding that traditional blood pressure categorizations have hitherto overlooked. This relationship is consistent across subgroup analyses, regardless of the stratification by sex and age. Given that nearly half of the cohort exhibited varying degrees of hypertension, the 8.2% prevalence of diastolic dominant hypertension represents a significant subgroup.

Recent evidence from large-scale randomized controlled trials has prompted a reevaluation of blood pressure targets, advocating a systolic pressure below 130 mmHg and a diastolic pressure below 80 mmHg[9,20,21]. Nonetheless, a crucial question persists: at what blood pressure threshold does therapeutic intervention yield clinical benefit? The World Health Organization's guidelines for hypertension recommend the timely initiation of antihypertensive therapy in patients with blood pressure exceeding 140/90 mmHg[22]. However, the Chinese guidelines for the prevention and treatment of hypertension recommend lifestyle modifications and non-pharmacological approaches as first-line treatments for patients with blood pressure below 160/100mmHg, reserving pharmacological treatment for those with more severe disease stages[23]. Our findings robustly supports the latter view, demonstrating that individuals with blood pressure below 160/100mmHg—whether characterized by systolic dominance, diastolic dominance, or concurrent elevation—did not experience increased cardiovascular risk over nearly five years of follow-up. Thus, prioritizing non-pharmacological strategies in this cohort appears justified and feasible. Concurrently, we made comparisons with the previous SPRINT study conducted in the United States, which enrolled over 9,000 hypertensive patients who were over 50 years old and had at least one cardiovascular risk factor, classifying them as 'high-risk'[24]. By comparing the intensive treatment group (with an SBP target of < 120 mmHg) to the standard treatment group (with an SBP target of < 140 mmHg), the study concluded that intensive treatment to maintain SBP below 120 mmHg could reduce the occurrence of cardiovascular events and decrease all-cause mortality compared to subjects with blood pressure controlled at 140 mmHg. However, the SPRINT study's cohort consisted of high cardiovascular risk patients, and intensive blood pressure lowering treatment provided better clinical benefits for them, further lowering cardiovascular risk but also increasing the incidence of adverse events due to hypotension. Our research is an observational cohort study within a natural population, which does not have high cardiovascular risk. From our observational study results, in patients with Stage 1 hypertension, no significant increase in cardiovascular risk was observed compared to subjects with normal blood pressure. Therefore, whether intensive blood pressure control is required for this part of the natural population, whether intensive blood pressure reduction could further decrease their cardiovascular risk, and whether it might lead to severe adverse events due to hypotension, needs to be confirmed by more future Randomized Controlled Trials (RCTs).

Moreover, the study introduces a pertinent debate: for individuals with diastolic dominant hypertension at Grade 2 or higher, who do not show heightened cardiovascular risk, the necessity and timing of initiating pharmacological intervention merit further discussion. Current evidence highlights various conditions that may induce secondary diastolic hypertension, such as chronic kidney disease and thyroid disease, with potential pathophysiological underpinnings including sodium and water retention, alterations in hormonal balance leading to abnormalities in cardiac contractile function, and changes in peripheral vascular resistance[25,26]. Consequently, in clinical practice, more emphasis should be placed on screening for and managing secondary causes of diastolic dominant hypertension.

	Incidence N	Total N	HR	95%CI	P
Male					
N	53	2074	-	-	-
S1	30	691	1.092	0.690–1.729	**0.707**
D1	4	76	2.271	0.816–6.320	**0.116**
S1D1	16	327	1.808	1.025–3.189	0.041
S2	32	355	1.865	1.176–2.957	0.008
D2	5	71	2.293	0.906–5.805	**0.080**
S2D2	11	103	3.339	1.711–6.513	<0.001
S3	30	171	3.300	2.048–5.315	<0.001
D3	1	24	2.077	0.284–15.189	**0.471**
S3D3	7	33	8.152	4.303–17.461	<0.001
Female					
N	66	2684	-	-	-
S1	35	709	1.242	0.690–1.729	**0.324**
D1	2	69	1.009	0.816–6.320	**0.991**
S1D1	11	252	0.932	1.025–3.189	**0.861**
S2	21	308	1.380	1.176–2.957	**0.227**
D2	0	33	0.015	0.906–5.805	**0.688**
S2D2	4	45	2.987	1.711–6.513	0.036
S3	11	141	1.365	2.048–5.315	**0.369**
D3	1	6	3.717	0.284–15.189	**0.197**
S3D3	3	19	5.546	4.803–21.461	0.004
Age<55 years					
N	38	3380	-	-	-
S1	11	654	1.082	0.547–2.138	**0.829**
D1	3	108	2.034	0.622–6.650	**0.248**
S1D1	11	374	1.864	0.942–3.692	**0.076**
S2	10	203	2.952	1.438–6.059	<0.001
D2	1	65	0.969	0.131–7.169	**0.954**
S2D2	7	85	5.257	2.291–12.063	<0.001
S3	7	72	5.468	2.394–12.493	<0.001
D3	1	25	2.497	0.332–18.871	**0.389**
S3D3	3	25	6.688	1.991–22.463	0.002
Age ≥ 55 years					
	Incidence N	Total N	HR	95%CI	P
N	81	1378	-	-	-
S1	54	746	1.105	0.779–1.569	**0.575**
D1	3	37	1.304	0.410–4.145	**0.653**
S1D1	16	205	1.054	0.572–1.941	**0.866**
S2	43	460	1.324	0.905–1.937	**0.148**
D2	4	39	1.792	0.651–4.928	**0.259**
S2D2	8	63	2.186	1.043–4.583	0.038
S3	34	240	1.983	1.305–3.012	0.001
D3	1	5	2.282	0.315–16.554	**0.414**
S3D3	7	27	5.753	2.618–12.641	<0.001

Table 3. Subgroup analysis based on sex and age.

Pathologically, SBP informs about the left ventricular ejection function, whereas DBP reflects arterial resistance; both parameters carry distinct and equally important clinical and prognostic implications[27]. In the elderly, vascular wall degeneration, loss of elasticity, and atherosclerotic changes, particularly in the aortic wall and elastic arteries, attenuate the capacity for systolic distension, leading to elevated SBP[28,29]. In contrast, younger hypertensive individuals often experience a rise in diastolic pressure due to increased peripheral resistance[30]. These disparate pathophysiological mechanisms imply that while patients may be categorized under the same hypertension grade, their associated cardiovascular risks differ. The prevailing consensus is that SBP has a greater prognostic value for cardiovascular risk than DBP[31]. Nevertheless, emerging research underscores that elevations in both SBP and DBP independently contribute to the risk of adverse cardiovascular events, a

fact that should not be neglected[32]. Recent investigations have begun to parse out the distinct impacts of SBP and DBP on cardiovascular risk; however, these studies have largely focused on isolated systolic or diastolic hypertension or have treated SBP and DBP as separate entities[30,33,34], which lacks comprehensiveness and limits generalizability. Additionally, the cardiovascular risk associated with nonparallel SBP and DBP elevations has been insufficiently characterized.

To date, scholarly discourse that examines SBP and DBP in graded detail remains limited. Yano Y et al.'s study delineated the population into non-hypertensive, Grade 1, and Grade 2 hypertension, discussing cardiovascular risk in these distinct categories, reaching the conclusion that those with elevated blood pressure, stage 1 hypertension, and stage 2 hypertension before age 40 years had significantly higher risk for subsequent cardiovascular disease events compared with those with normal blood pressure before age 40 years[35]. Bo Y et al. expanded on this by differentiating between systolic and diastolic hypertension within Grades 1 and 2, focusing on all-cause and cardiovascular mortality as endpoints, reaching the results that young adults with stage 1 or stage 2 isolated systolic hypertension, isolated diastolic hypertension, and systolic and diastolic hypertension are at increased risk of cardiovascular death than those with normal BP[36]. Our study pioneers the integration of all potential SBP and DBP levels to forge new blood pressure classifications, unveiling significant disparities in cardiovascular risk across different grades. Moreover, our study provides an innovative perspective on the current strategies for blood pressure classification: considering systolic and diastolic blood pressures separately when categorizing patient blood pressure levels. This approach accounts for the impact of the degree of blood pressure elevation while differentiating between diastolic and systolic pressures, allowing for a more scientific assessment of the cardiovascular disease risk in subjects

Nevertheless, our study is not without limitations. The cohort size, while substantial, was under 10,000 participants—a sample that could benefit from expansion in future research. Additionally, the initial follow-up phase spanned 4.66 years. Comprehensive assessments of long-term cardiovascular risk among our subjects necessitate prolonged follow-up periods in subsequent studies. Furthermore, in our study, risk stratification of patients considered only the impact of blood pressure without incorporating other cardiovascular risk factors. Although our analysis adjusted for these risk factors and yielded valid conclusions, a more scientific approach to risk stratification should initially include these factors. However, a comprehensive assessment of subjects requires a full understanding of the patient's overall condition, particularly regarding target organ damage, such as retinopathy[22], which is a complex and extensive task. Our study was unable to fully address these issues, which is a limitation of our work. We look forward to future research that may overcome this deficiency.

Conclusion

Given the distinct cardiovascular risks identified in our study for patients with systolic-dominant hypertension, diastolic-dominant hypertension, and parallelly-elevated hypertension, we propose a tailored approach to management. For individuals diagnosed with Grade 1 hypertension and those exhibiting diastolic-dominant hypertension, lifestyle modifications should be the initial intervention. Furthermore, proactive screening for and management of secondary causes of hypertension—particularly those that elevate diastolic pressure—are recommended before the commencement of pharmacological treatment. Our findings contribute a novel insight into the optimization of risk stratification and therapeutic strategies for hypertension, suggesting the potential benefits of individualized patient care pathways.

Data availability

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation. If the data from this study is requested， please contact Xingang Zhang，zhangxingang80@aliyun.com.

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Author contributions

YS, YC and XZ directed the design of study. PW was responsible for the study conduct and methodology. QL analyzed the data and wrote the manuscript. YC and XZ contributed equally to the manuscript. All authors contributed to the article and approved the submitted version.

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Declarations

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Additional information

Correspondence and requests for materials should be addressed to Y.C. or X.Z.