ORIGINAL RESEARCH

Prevalence, Awareness, and Treatment of Isolated Diastolic Hypertension: Insights From the China PEACE Million Persons Project

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***Background*—**Characterizing and assessing the prevalence, awareness, and treatment patterns of patients with isolated diastolic hypertension (IDH) can generate new knowledge and highlight opportunities to improve their care.

***Methods and Results*—**We used data from the China PEACE (Patient-centered Evaluative Assessment of Cardiac Events) Million Persons Project, which screened 2 351 035 participants aged 35 to 75 years between 2014 and 2018. IDH was defined as systolic and diastolic blood pressure of <140 and ≥90 mm Hg; awareness as self-reported diagnosis of hypertension; and treatment as current use of antihypertensive medications. Of the 2 310 184 participants included (mean age 55.7 years; 59.5% women); 73 279 (3.2%) had IDH, of whom 63 112 (86.1%) were untreated, and only 6512 (10.3%) of the untreated were aware of having hypertension. When compared with normotensives, participants who were <60 years, men, at least college educated, had body mass index of >28 kg/m^2, consumed alcohol, had diabetes mellitus, and prior cardiovascular events were more likely to have IDH (all P<0.01). Among those with IDH, higher likelihood of awareness was associated with increased age, women, college education, body mass index of >28 kg/m^2, higher income, diabetes mellitus, prior cardiovascular events, and Central or Eastern region (all P<0.05). Most treated participants with IDH reported taking only 1 class of antihypertensive medication.

***Conclusions*—**IDH affects a substantial number of people in China, however, few are aware of having hypertension and most treated participants are poorly managed, which suggests the need to improve the diagnosis and treatment of people with IDH.
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Key Words: awareness • hypertension subtypes • isolated diastolic hypertension • prevalence • treatment

Isolated diastolic hypertension (IDH), whether in treated or untreated patients, is an uncommon type of hypertension accounting for <20% of hypertension cases.[1–4] Nevertheless, IDH is independently associated with an increased risk of stroke, heart disease, and the other sequelae of hypertension.[5–14] However, the most recent US, Chinese, and

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Accompanying Data S1, Tables S1, S2, and Figures S1 through S5 are available at https://www.ahajournals.org/doi/suppl/10.1161/JAHA.119.012954

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Clinical Perspective

What Is New?

- This is one of the largest population-based studies to evaluate the characteristics, prevalence, awareness, and treatment patterns of individuals with isolated diastolic hypertension (IDH) in China, allowing us to draw robust conclusions across diverse subgroups.
- We found that IDH affected a large number of adults in China, and these patients had some unique characteristics as compared with people without hypertension as well as those with other types of hypertension.
- Awareness of hypertension was significantly lower among people with IDH as compared with other types of hypertension, and most participants with IDH despite treatment had scope for further intensification of therapy.

What Are the Clinical Implications?

- Given that diastolic hypertension can independently influence the risk of adverse cardiovascular events, identifying characteristics that may be associated with IDH and understanding the current awareness and treatment patterns among those with IDH can help identify the patients at increased cardiovascular risk and highlight opportunities to improve their care.
- Focusing on people with IDH and improving their diagnosis and treatment, may be critical to mitigate the burden of hypertension, especially in the young- and middle-aged population.

European high blood pressure guidelines do not specifically address IDH as a distinct phenotype or provide any specific guidance for its management.[15–17]

Although many studies have focused on patient characteristics, knowledge, and treatment, patients with IDH constitute a small subset of all patients with hypertension, and have traditionally been included within the total population of hypertensive patients,[1,18–20] even though they may have unique features.[20,21] Given its low prevalence, a large sample size would be required to fully capture the range of attributes of individuals with IDH across diverse population subgroups, and draw robust conclusions with high precision. Characterizing these patients specifically and assessing their awareness and treatment patterns can generate new knowledge about this distinct subtype of hypertension. This information will not only expand our knowledge about the IDH phenotype, but could also equip us to identify targets for improvement of care.

Accordingly, we sought to identify and study patients with IDH, whether treated or untreated, using data from the China PEACE (Patient-centered Evaluative Assessment of Cardiac Events) Million Persons Project, a large-scale population-based screening project which was initiated with the aim of providing detailed information on smaller subgroups of patients who have traditionally been hard to identify in the population. We sought to describe the characteristics and prevalence of individuals with IDH across diverse population subgroups among both untreated and treated hypertensives; assess awareness of having hypertension among untreated IDH participants; assess the number and classes of medications used by treated participants with IDH; and identify the associations between individual characteristics with prevalence of, and awareness among those with IDH. Although some of the treated patients may be individuals who initially had systolic and diastolic hypertension, but with medications have only diastolic hypertension, this does represent the spectrum of patients who would be seen in practice with IDH, either as a de novo condition or as inadequately treated diastolic hypertension. Moreover, the treatment rates in China are sufficiently low that the population with IDH largely represents those with the de novo condition.

Methods

The China PEACE Million Persons Project is a major national program, and as the government policy stipulates, it is not permissible for the researchers to make the raw data publicly available at this time.

Study Design and Population

Details of the China PEACE Million Persons Project have been described previously.[22,23] Briefly, we used a convenience sampling strategy to select 184 sites (111 rural counties and 73 urban districts) from all 31 provinces in mainland China. People were encouraged to participate in the project through publicity campaigns in the newspaper and on the television. Of the 2 351 035 participants aged 35 to 75 years enrolled at these sites between September 15, 2014 and May 29, 2018, we excluded 14 904 participants because of missing or extreme blood pressure values (systolic blood pressure [SBP] <70 or >270 mm Hg; diastolic blood pressure [DBP] <30 or >150 mm Hg), 142 participants due to missing or extreme body mass index values (<10 or >50 kg/m^2), and 25 805 participants due to missing data on covariates, including geographical region, education, occupation, marital status, household income, and alcohol use (Figure S1).

Blood Pressure Collection and Classification

For every participant, blood pressure was measured twice at enrollment, at an interval of 1 minute, on their right upper arm using an electronic blood pressure monitor (Omron HEM-7430;

Omron Corporation, Kyoto, Japan) after 5 minutes of rest in the seated position. The values of both the readings as well as their mean were recorded. If the difference between the 2 SBP measurements was >10 mm Hg, a third blood pressure reading was taken and the mean SBP and DBP was calculated using the last 2 readings in such cases. The mean SBP and DBP were used for all calculations. Additionally, information was collected on any prescription drugs taken by the participants in the past 2 weeks for antiplatelet, blood pressure, lipid, or glucose control during an in-person interview.

Since this study was done in a Chinese cohort, we used the Chinese Guidelines for the Management of Hypertension to define hypertension and classify patients with hypertension into different hypertension subtypes.[15] Participants were considered to have hypertension if they had an average SBP of at least 140 mm Hg or an average DBP of at least 90 mm Hg or self-reported use of an antihypertensive medication in the past 2 weeks. IDH was defined as an average SBP of <140 mm Hg but a DBP of at least 90 mm Hg. We defined IDH based on the participant's SBP and DBP at the time of screening, and the IDH group included both untreated IDH participants and those with IDH despite antihypertensive medication. The "other hypertensive subtypes" group included all hypertensives, except those with IDH, including participants with isolated systolic hypertension (ISH; SBP ≥140 mm Hg and DBP <90 mm Hg), combined systolic-diastolic hypertension (SDH; SBP ≥140 mm Hg and DBP ≥90 mm Hg), and controlled hypertensives (participants who reported having a history of hypertension or taking antihypertensive medications but had an SBP <140 mm Hg and a DBP <90 mm Hg). Participants who did not have a history of hypertension or antihypertensive medication use and who had an SBP <140 mm Hg and a DBP <90 mm Hg were defined as normotensives.

Participants were considered to be aware of their hypertension if they responded "yes" to the question "Have you ever been diagnosed with hypertension?". Participants were considered to be receiving treatment for hypertension if they reported using antihypertensive medication (Western or traditional Chinese medication) currently or within the last 2 weeks.

Independent Variables

Information on the participants' sociodemographic characteristics, health behaviors, medical history, and cardiovascular risk factors was recorded during in-person interviews as described previously.[22] Height and weight were collected using standard protocols, and body mass index (BMI) was calculated by dividing the weight in kilograms by the square of height in meters. Obesity was defined as a BMI of at least 28 kg/m^2, which was in accordance with the recommendations of the Working Group on Obesity in China.[24]

We also formed diverse, mutually exclusive subgroups, to assess if some population subgroups had higher or lower rates of prevalence and awareness compared with the average rates of the total population. These subgroups were defined a priori by all possible combinations of 10 characteristics: age group (35–44, 45–54, 55–64, and 65–75 years), sex (men, women), geographic region (Western, Central, Eastern), urbanity (urban, rural), occupation (farmer, non-farmer), annual household income (<10 000, 10 000–50 000, and >50 000 Yuan/year), education (primary school and below, middle school, high school, college and above), prior cardiovascular events (myocardial infarction or stroke; yes versus no), current smoker (yes versus no), and diabetes mellitus (yes versus no).

Statistical Analysis

We assessed the prevalence of IDH among the overall study population and among hypertensive participants (both overall and among untreated and treated hypertensives) and compared the prevalence of IDH with other hypertension subtypes across different age groups. We also calculated age- and sex-standardized prevalence of IDH at the national level, standardizing against data from all 31 provinces in the 2010 Chinese Census. We then described the characteristics of participants with IDH and compared these with normotensive as well as with other hypertensive subgroups, and described the characteristics of untreated and treated participants with IDH separately. Next, we assessed the awareness of hypertension among untreated IDH participants across different population characteristics; and compared the awareness rates of untreated IDH participants with those of untreated ISH and SDH participants across different age groups. We assessed awareness only among untreated IDH participants as some treated participants with IDH may have adequately lowered their DBP and moved to the controlled hypertensive group, thus underestimating awareness rates among those having IDH despite treatment. The statistical significance of the differences between groups was assessed using Pearson Chi-squared test.

We retained 1198 mutually exclusive subgroups of at least 200 participants each, which included 84.1% of the participants with IDH, and calculated the prevalence of IDH among all study participants and the awareness rates among untreated IDH participants. We also used histograms to show the rate distributions, and repeated the analysis by restricting to 731 subgroups containing at least 500 participants each (which included 77.6% of the participants with IDH).

Among participants who had IDH despite treatment, we assessed the number and class of medications reported by them. Medication usage was divided into 6 medication classes defined by the 2010 Chinese guidelines for the

Table 1. Baseline Characteristics of Participants With Isolated Diastolic Hypertension Compared With Normotensives and Other Hypertensives

Characteristics, n (%)	Normotensives	Isolated Diastolic Hypertension	Other Hypertensives
n (%)	1 286 404 (55.7%)	73 279 (3.2%)	950 501 (41.1%)
Age, y			
35 to 39	91 686 (7.1%)	4603 (6.3%)	14 056 (1.5%)
40 to 44	181 177 (14.1%)	10 538 (14.4%)	45 006 (4.7%)
45 to 49	229 912 (17.9%)	15 328 (20.9%)	91 801 (9.7%)
50 to 54	235 412 (18.3%)	16 479 (22.5%)	149 641 (15.7%)
55 to 59	170 190 (13.2%)	10 082 (13.8%)	147 992 (15.6%)
60 to 64	182 963 (14.2%)	8910 (12.2%)	205 833 (21.7%)
65 to 69	123 906 (9.6%)	4985 (6.8%)	176 376 (18.6%)
70 to 75	71 158 (5.5%)	2354 (3.2%)	119 796 (12.6%)
Sex			
Men	501 100 (39.0%)	42 360 (57.8%)	392 040 (41.2%)
Women	785 304 (61.0%)	30 919 (42.2%)	558 461 (58.8%)
Urbanity			
Urban	517 420 (40.2%)	26 309 (35.9%)	345 720 (36.4%)
Rural	768 984 (59.8%)	46 970 (64.1%)	604 781 (63.6%)
Region			
Eastern	416 104 (32.3%)	23 902 (32.6%)	352 929 (37.1%)
Western	494 433 (38.4%)	28 156 (38.4%)	308 351 (32.4%)
Central	375 867 (29.2%)	21 221 (29.0%)	289 221 (30.4%)
Education			
Primary school or lower	512 301 (39.8%)	26 212 (35.8%)	473 213 (49.8%)
Middle school	432 275 (33.6%)	25 959 (35.4%)	288 724 (30.4%)
High school	211 349 (16.4%)	12 368 (16.9%)	126 468 (13.3%)
College or above	111 560 (8.7%)	7602 (10.4%)	49 895 (5.2%)
Unknown*	18 919 (1.5%)	1138 (1.6%)	12 201 (1.3%)
Employment			
Employed	963 858 (74.9%)	57 582 (78.6%)	649 247 (68.3%)
Unemployed	17 294 (1.3%)	1345 (1.8%)	11 630 (1.2%)
Retired	185 763 (14.4%)	8342 (11.4%)	191 626 (20.2%)
Housework	95 722 (7.4%)	4470 (6.1%)	83 403 (8.8%)
Unknown*	23 767 (1.8%)	1540 (2.1%)	14 595 (1.5%)
Occupation			
Farmer	602 369 (46.8%)	34 562 (47.2%)	492 275 (51.8%)
Non-farmer	660 268 (51.3%)	37 177 (50.7%)	443 631 (46.7%)
Unknown*	23 767 (1.8%)	1540 (2.1%)	14 595 (1.5%)
Household income, Yuan/y			
<10 000	256 630 (19.9%)	14 307 (19.5%)	216 481 (22.8%)
10 000 to 50 000	711 228 (55.3%)	40 359 (55.1%)	521 951 (54.9%)
>50 000	199 441 (15.5%)	11 908 (16.3%)	128 457 (13.5%)
Unknown*	119 105 (9.3%)	6705 (9.1%)	83 612 (8.8%)

Continued

Table 1. Continued

Characteristics, n (%)	Normotensives	Isolated Diastolic Hypertension	Other Hypertensives
Marital status			
Married	1 208 737 (94.0%)	69 159 (94.4%)	869 211 (91.4%)
Widowed, separated, divorced, single	61 396 (4.8%)	3192 (4.4%)	70 389 (7.4%)
Unknown*	16 271 (1.3%)	928 (1.3%)	10 901 (1.1%)
Health insurance status			
Insured	1 258 190 (97.8%)	71 580 (97.7%)	932 199 (98.1%)
Uninsured	8388 (0.7%)	502 (0.7%)	4890 (0.5%)
Unknown*	19 826 (1.5%)	1197 (1.6%)	13 412 (1.4%)
Medical history			
Myocardial infarction	6281 (0.5%)	496 (0.7%)	10 447 (1.1%)
Stroke	15 628 (1.2%)	1614 (2.2%)	38 626 (4.1%)
Diabetes mellitus	51 410 (4.0%)	3499 (4.8%)	93 329 (9.8%)
Cardiovascular disease risk factor			
Current smoker	249 422 (19.4%)	20 667 (28.2%)	185 778 (19.5%)
Current drinker	292 489 (22.7%)	26 529 (36.2%)	240 183 (25.3%)
Obesity	134 244 (10.4%)	17 241 (23.5%)	214 058 (22.5%)

P-value <0.001 for all comparisons among the 3 groups.
*Participants either refused to answer the question or did not know the answer.

management of hypertension[15] and included angiotensin-converting enzyme inhibitors or angiotensin receptor blockers, beta-blockers, calcium channel blockers, diuretics, and fixed-dose combination drugs. We also collected information on the traditional Chinese medications (TCMs) used for hypertension. To assess whether the management of IDH patients varied by severity, we stratified them into 3 groups based on the degree DBP elevation (90–95, 96–100, and >100 mm Hg) and compared the most frequently used antihypertensive medication class and the number of antihypertensive medications used by patients in each of these groups.

Finally, we developed 2 multivariable generalized linear mixed models with a logit link function and township-specific random intercepts (to account for geographic autocorrelation) to identify individual characteristics associated with prevalence of IDH, and the awareness of hypertension among untreated IDH participants (details in Data S1). For identifying the characteristics associated with IDH, we compared IDH participants with both normotensives as well as other hypertensives using 2 separate models. Explanatory variables included participants' age, sex, marital status, annual household income, education level, occupation, geographical region, health insurance status, smoking, alcohol use, obesity, physician-diagnosed diabetes mellitus (DM), and prior cardiovascular events (myocardial infarction or stroke).

All analyses were conducted using R 3.33 (The R Foundation for Statistical Computing, Vienna, Austria) and SAS 9.4 (SAS Institute Inc, Cary, NC). The central ethics committee at the China National Center for Cardiovascular Disease and the Internal Review Board at Yale University approved this project, and written informed consent was obtained from all enrolled participants.

Results

Population Characteristics

Our sample included 2 310 184 participants with a mean age of 55.7 (SD 9.8) years; 1 374 684 (59.5%) were women; and 1 023 780 (44.3%) had hypertension. Compared with the population aged 35 to 75 years in the 2010 Chinese Census, our sample contained more people from older age groups (70.4% of people with age 50 and older in the Million Persons Project versus 46.1% in Census).

Prevalence and Characteristics of Participants With IDH

Overall, 73 279 (3.2% of the study population and 7.2% of hypertensives) participants had IDH and 950 501 (41.1% of the study population) participants had other types of hypertension (including, 469 349 [20.3%] with ISH, 403 912 [17.5%] with SDH, and 77 240 [3.3%] with controlled hypertension). When we standardized our results to national census-based estimates, we found a higher prevalence of

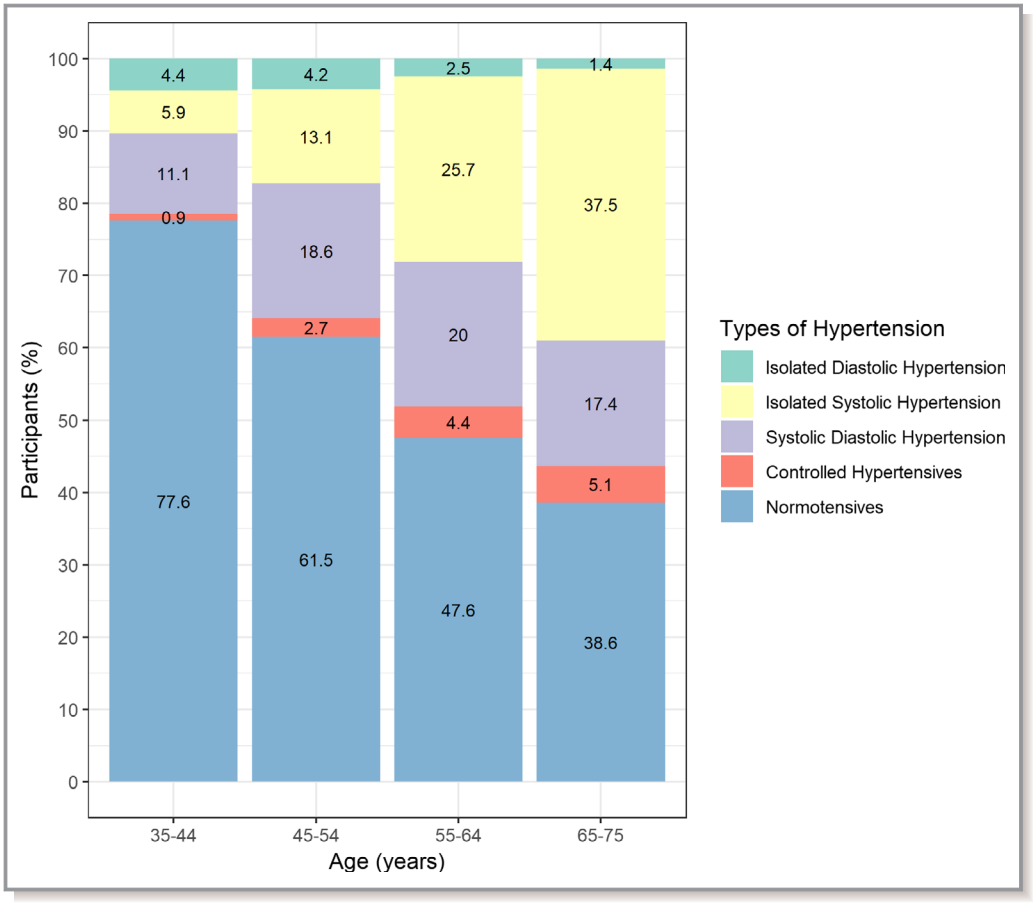

Figure 1. Prevalence of isolated diastolic hypertension and other types of hypertension (isolated systolic hypertension, systolic-diastolic hypertension, and controlled hypertension), by age group.

IDH (3.8%) but a lower prevalence of other hypertension subgroups (34.0%). Overall, participants with IDH were more likely to be younger, men, employed, married, more educated, have higher income, consume alcohol, be current smoker, and obese than those who were normotensive or who had other types of hypertension (all $P<0.001$; Table 1). Additionally, participants with IDH were more likely to have a history of myocardial infarction, stroke, and DM (0.7%, 2.2%, and 4.8% respectively) when compared with normotensive participants (0.5%, 1.2%, and 4.0% respectively), and less likely to have a history of myocardial infarction, stroke, and DM compared with participants with other types of hypertension (1.1%, 4.1%, and 9.8% respectively). Both untreated and treated IDH participants had similar characteristics (Table S1).

The prevalence of IDH decreased with age, whereas the prevalence of other hypertension subtypes (including ISH, SDH and controlled hypertensives) increased with age (Figure 1). The prevalence of IDH was significantly higher for men (4.5% of overall population and 9.8% of hypertensives) as compared with women (2.2% of overall population and 5.2% of hypertensives; Table 2). The prevalence was also significantly higher among those living in rural areas and Western regions, who were at least college educated, and had a higher income (Table 2). Prevalence of IDH showed a similar distribution across different population subgroups in both treated and untreated hypertensive participants (Table 3 and Table S2).

The 1198 subgroups varied with respect to the prevalence of participants with IDH (median: 2.9%, [IQR: 1.7–4.7]; Figure S2). The prevalence of IDH was substantially higher in subgroups with participants who were younger, men, without prior cardiovascular event, and without DM as compared with participants who were older, women, with prior cardiovascular event, and with DM (Figure 2). Subgroups with at least 500 participants had similar results (Figures S3 and S4).

In mixed effects multivariable logistic regression analysis assessing independent predictors of IDH, we identified several individual characteristics associated with the prevalence of IDH (Table 4). When compared with normotensives, participants who were young- and middle-aged, men, were at least college educated, consumed alcohol, had DM, were obese, and had prior cardiovascular events were more likely to have IDH than those who were older, women, less educated, did not consume alcohol, were not obese, and did not have DM or prior cardiovascular events (all $P<0.01$). Participants who

Table 2. Prevalence of Isolated Diastolic Hypertension Among All Participants and Hypertensive Participants, by Population Characteristics

Characteristics	All Participants		Hypertensive Participants	
	n	Prevalence of IDH n (%, 95% CI)	n	Prevalence of IDH n (%, 95% CI)
n (%, 95% CI)	2 310 184	73 279 (3.2%, 3.1–3.2)	1 023 780	73 279 (7.2%, 7.1–7.2)
Age, y				
35 to 39	110 345	4603 (4.2%, 4.1–4.3)	18 659	4603 (24.7%, 24.1–25.3)
40 to 44	236 721	10 538 (4.5%, 4.4–4.5)	55 544	10 538 (19.0%, 18.6–19.3)
45 to 49	337 041	15 328 (4.5%, 4.5–4.6)	107 129	15 328 (14.3%, 14.1–14.5)
50 to 54	401 532	16 479 (4.1%, 4.0–4.2)	166 120	16 479 (9.9%, 9.8–10.1)
55 to 59	328 264	10 082 (3.1%, 3.0–3.1)	158 074	10 082 (6.4%, 6.3–6.5)
60 to 64	397 706	8910 (2.2%, 2.2–2.3)	214 743	8910 (4.1%, 4.1–4.2)
65 to 69	305 267	4985 (1.6%, 1.6–1.7)	181 361	4985 (2.7%, 2.7–2.8)
70 to 75	193 308	2354 (1.2%, 1.2–1.3)	122 150	2354 (1.9%, 1.9–2.0)
Sex				
Men	935 500	42 360 (4.5%, 4.5–4.6)	434 400	42 360 (9.8%, 9.7–9.8)
Women	1 374 684	30 919 (2.2%, 2.2–2.3)	589 380	30 919 (5.2%, 5.2–5.3)
Urbanity				
Urban	889 449	26 309 (3.0%, 2.9–3.0)	372 029	26 309 (7.1%, 7.0–7.2)
Rural	1 420 735	46 970 (3.3%, 3.3–3.3)	651 751	46 970 (7.2%, 7.1–7.3)
Region				
Eastern	792 935	23 902 (3.0%, 3.0–3.1)	376 831	23 902 (6.3%, 6.3–6.4)
Western	830 940	28 156 (3.4%, 3.3–3.4)	336 507	28 156 (8.4%, 8.3–8.5)
Central	686 309	21 221 (3.1%, 3.1–3.1)	310 442	21 221 (6.8%, 6.7–6.9)
Education				
Primary school or lower	1 011 726	26 212 (2.6%, 2.6–2.6)	499 425	26 212 (5.2%, 5.2–5.3)
Middle school	746 958	25 959 (3.5%, 3.4–3.5)	314 683	25 959 (8.2%, 8.2–8.3)
High school	350 185	12 368 (3.5%, 3.5–3.6)	138 836	12 368 (8.9%, 8.8–9.1)
College or above	169 057	7602 (4.5%, 4.4–4.6)	57 497	7602 (13.2%, 12.9–13.5)
Unknown*	32 258	1138 (3.5%, 3.3–3.7)	13 339	1138 (8.5%, 8.1–9.0)
Employment				
Employed	1 670 687	57 582 (3.4%, 3.4–3.5)	706 829	57 582 (8.1%, 8.1–8.2)
Unemployed	30 269	1345 (4.4%, 4.2–4.7)	12 975	1345 (10.4%, 9.8–10.9)
Retired	385 731	8342 (2.2%, 2.1–2.2)	199 968	8342 (4.2%, 4.1–4.3)
Housework	183 595	4470 (2.4%, 2.4–2.5)	87 873	4470 (5.1%, 4.9–5.2)
Unknown*	39 902	1540 (3.9%, 3.7–4.0)	16 135	1540 (9.5%, 9.1–10.0)
Occupation				
Farmer	1 129 206	34 562 (3.1%, 3.0–3.1)	526 837	34 562 (6.6%, 6.5–6.6)
Non-farmer	1 141 076	37 177 (3.3%, 3.2–3.3)	480 808	37 177 (7.7%, 7.7–7.8)
Unknown*	39 902	1540 (3.9%, 3.7–4.0)	16 135	1540 (9.5%, 9.1–10.0)
Household income, Yuan/y				
<10 000	487 418	14 307 (2.9%, 2.9–3.0)	230 788	14 307 (6.2%, 6.1–6.3)
10 000 to 50 000	1 273 538	40 359 (3.2%, 3.1–3.2)	562 310	40 359 (7.2%, 7.1–7.2)

Continued

Table 2. Continued

Characteristics	All Participants		Hypertensive Participants	
	n	Prevalence of IDH n (%, 95% CI)	n	Prevalence of IDH n (%, 95% CI)
>50 000	339 806	11 908 (3.5%, 3.4–3.6)	140 365	11 908 (8.5%, 8.3–8.6)
Unknown*	209 422	6705 (3.2%, 3.1–3.3)	90 317	6705 (7.4%, 7.3–7.6)
Marital status				
Married	2 147 107	69 159 (3.2%, 3.2–3.2)	938 370	69 159 (7.4%, 7.3–7.4)
Widowed, separated, divorced, single	134 977	3192 (2.4%, 2.3–2.4)	73 581	3192 (4.3%, 4.2–4.5)
Unknown*	28 100	928 (3.3%, 3.1–3.5)	11 829	928 (7.8%, 7.4–8.3)
Health insurance status				
Insured	2 261 969	71 580 (3.2%, 3.1–3.2)	1 003 779	71 580 (7.1%, 7.1–7.2)
Uninsured	13 780	502 (3.6%, 3.3–4.0)	5392	502 (9.3%, 8.5–10.1)
Unknown*	34 435	1197 (3.5%, 3.3–3.7)	14 609	1197 (8.2%, 7.7–8.6)
Medical history				
Myocardial infarction	17 224	496 (2.9%, 2.6–3.1)	10 943	496 (4.5%, 4.1–4.9)
Stroke	55 868	1614 (2.9%, 2.8–3.0)	40 240	1614 (4.0%, 3.8–4.2)
Diabetes mellitus	148 238	3499 (2.4%, 2.3–2.4)	96 828	3499 (3.6%, 3.5–3.7)
CVD risk factor				
Current smoker	455 867	20 667 (4.5%, 4.5–4.6)	206 445	20 667 (10.0%, 9.9–10.1)
Current drinker	559 201	26 529 (4.7%, 4.7–4.8)	266 712	26 529 (9.9%, 9.8–10.1)
Obesity	365 543	17 241 (4.7%, 4.6–4.8)	231 299	17 241 (7.5%, 7.3–7.6)

CVD indicates cardiovascular disease; IDH, isolated diastolic hypertension.
*Participants either refused to answer the question or did not know the answer.

were married, farmers, and current smokers were less likely to have IDH (all $P<0.001$). Income and health insurance did not have a significant association with prevalence of IDH. Similarly, when compared with participants with other hypertension subtypes, participants who were younger, men, were at least college educated, and consumed alcohol were more likely to have IDH (all $P<0.001$); whereas, participants who were older, farmer, current smokers, had DM, were obese, had prior cardiovascular events, and belonged to the Central or Eastern regions were more likely to have other types of hypertension (all $P<0.001$).

Awareness of Having Hypertension Among Untreated Participants

Among untreated IDH participants (n=63 112 or 86.1% of the overall IDH group), only 6512 (or 10.3%) were aware of having hypertension, whereas 72 220 (or 24.8%) of the 290 645 untreated ISH and 89 516 (or 44.1%) of the 203 173 untreated SDH participants were aware of having hypertension. Awareness among untreated participants across all subtypes of hypertension increased with age; however, awareness among participants with IDH was significantly lower than other hypertensives (ISH and SDH), across all age groups (Figure 3; $P<0.005$ for all age -groups). The awareness rates were higher among those who lived in rural areas or Eastern or Central regions, were retired, had a higher income, and were widowed/separated/or divorced (Table 3). Fewer than 15% of the IDH participants with at least 1 or more cardiovascular risk factors (including smoking, alcohol use, and obesity) and <33% of IDH participants with a prior cardiovascular event or DM were aware of having hypertension. The 1198 subgroups varied with respect to awareness of having hypertension among untreated IDH participants (median: 9.7% [IQR: 4.0–17.6]; Figure S2). Awareness was higher in subgroups of participants who were older, had prior cardiovascular event, and had prior DM (Figure 4). Awareness rates were similar among men and women and in rural and urban areas. Subgroups with at least 500 participants had similar results (Figures S3 and S4).

We identified several independent factors associated with awareness of having hypertension among untreated IDH participants (Table 4). Awareness was significantly higher among IDH participants who were older, women, had higher income (>50 000 Yuan/year), were at least college educated,

Table 3. Prevalence and Awareness of Isolated Diastolic Hypertension Among Untreated Hypertensives, by Population Characteristics

Characteristics	Untreated Hypertensive Participants (n)	Prevalence of IDH n (%, 95% CI)	Awareness Among IDH Participants n (%, 95% CI)
n (%, 95% CI)	718 666	63 112 (8.8%, 8.7–8.8)	6512 (10.3%, 10.1–10.6)
Age, y			
35 to 39	16 425	4361 (26.6%, 25.9–27.2)	274 (6.3%, 5.6–7.0)
40 to 44	46 923	9658 (20.6%, 20.2–20.9)	633 (6.6%, 6.1–7.0)
45 to 49	84 788	13 560 (16.0%, 15.7–16.2)	1179 (8.7%, 8.2–9.2)
50 to 54	121 131	13 939 (11.5%, 11.3–11.7)	1551 (11.1%, 10.6–11.6)
55 to 59	109 324	8354 (7.6%, 7.5–7.8)	1022 (12.2%, 11.5–12.9)
60 to 64	144 370	7258 (5.0%, 4.9–5.1)	969 (13.4%, 12.6–14.1)
65 to 69	117 786	4062 (3.4%, 3.3–3.6)	619 (15.2%, 14.1–16.3)
70 to 75	77 919	1920 (2.5%, 2.4–2.6)	265 (13.8%, 12.3–15.3)
Sex			
Men	311 796	36 421 (11.7%, 11.6–11.8)	3777 (10.4%, 10.1–10.7)
Women	406 870	26 691 (6.6%, 6.5–6.6)	2735 (10.2%, 9.9–10.6)
Urbanity			
Urban	250 233	22 345 (8.9%, 8.8–9.0)	2187 (9.8%, 9.4–10.2)
Rural	468 433	40 767 (8.7%, 8.6–8.8)	4325 (10.6%, 10.3–10.9)
Region			
Eastern	259 305	20 374 (7.9%, 7.8–8.0)	2432 (11.9%, 11.5–12.4)
Western	240 487	24 697 (10.3%, 10.1–10.4)	1998 (8.1%, 7.7–8.4)
Central	218 874	18 041 (8.2%, 8.1–8.4)	2082 (11.5%, 11.1–12.0)
Education			
Primary school or lower	357 641	23 063 (6.4%, 6.4–6.5)	2450 (10.6%, 10.2–11.0)
Middle school	220 050	22 377 (10.2%, 10.0–10.3)	2292 (10.2%, 9.8–10.6)
High school	92 551	10 333 (11.2%, 11.0–11.4)	1035 (10.0%, 9.4–10.6)
College or above	38 218	6314 (16.5%, 16.1–16.9)	673 (10.7%, 9.9–11.4)
Unknown*	10 206	1025 (10.0%, 9.5–10.6)	62 (6.0%, 4.6–7.5)
Employment			
Employed	522 751	50 534 (9.7%, 9.6–9.7)	4909 (9.7%, 9.5–10.0)
Unemployed	8739	1109 (12.7%, 12.0–13.4)	147 (13.3%, 11.3–15.3)
Retired	116 143	6351 (5.5%, 5.3–5.6)	897 (14.1%, 13.3–15.0)
Housework	58 954	3761 (6.4%, 6.2–6.6)	441 (11.7%, 10.7–12.8)
Unknown*	12 079	1357 (11.2%, 10.7–11.8)	118 (8.7%, 7.2–10.2)
Occupation			
Famer	387 791	30 616 (7.9%, 7.8–8.0)	3040 (9.9%, 9.6–10.3)
Non-farmer	318 796	31 139 (9.8%, 9.7–9.9)	3354 (10.8%, 10.4–11.1)
Unknown*	12 079	1357 (11.2%, 10.7–11.8)	118 (8.7%, 7.2–10.2)
Household income, Yuan/y			
<10 000	168 343	12 725 (7.6%, 7.4–7.7)	1222 (9.6%, 9.1–10.1)
10 000 to 50 000	390 550	34 601 (8.9%, 8.8–8.9)	3462 (10.0%, 9.7–10.3)
>50 000	92 258	9903 (10.7%, 10.5–10.9)	1186 (12.0%, 11.3–12.6)

Continued

Table 3. Continued

Characteristics	Untreated Hypertensive Participants (n)	Prevalence of IDH n (%, 95% CI)	Awareness Among IDH Participants n (%, 95% CI)
Unknown*	67 515	5883 (8.7%, 8.5–8.9)	642 (10.9%, 10.1–11.7)
Marital status			
Married	662 083	59 671 (9.0%, 8.9–9.1)	6141 (10.3%, 10.0–10.5)
Widowed, separated, divorced, single	47 873	2629 (5.5%, 5.3–5.7)	321 (12.2%, 11.0–13.5)
Unknown*	8710	812 (9.3%, 8.7–9.9)	50 (6.2%, 4.5–7.8)
Health insurance status			
Insured	704 139	61 637 (8.8%, 8.7–8.8)	6371 (10.3%, 10.1–10.6)
Uninsured	4130	448 (10.8%, 9.9–11.8)	48 (10.7%, 7.9–13.6)
Unknown*	10 397	1027 (9.9%, 9.3–10.5)	93 (9.1%, 7.3–10.8)
Medical history			
Myocardial infarction	5167	334 (6.5%, 5.8–7.1)	99 (29.6%, 24.7–34.5)
Stroke	18 897	986 (5.2%, 4.9–5.5)	309 (31.3%, 28.4–34.2)
Diabetes mellitus	51 296	2521 (4.9%, 4.7–5.1)	650 (25.8%, 24.1–27.5)
CVD risk factor			
Current smoker	149 972	17 842 (11.9%, 11.7–12.1)	1847 (10.4%, 9.9–10.8)
Current drinker	193 777	22 740 (11.7%, 11.6–11.9)	2389 (10.5%, 10.1–10.9)
Obesity	146 456	13 970 (9.5%, 9.4–9.7)	1908 (13.7%, 13.1–14.2)

CVD indicates cardiovascular disease; IDH, isolated diastolic hypertension.
*Participants either refused to answer the question or did not know the answer.

obese, had DM, prior cardiovascular event, and belonged to Central or Eastern region (all $P<0.05$). Participant's marital status, occupation, health insurance status, and health behaviors like smoking and alcohol use, were not independently associated with their awareness of having hypertension.

Treatment Patterns Among Treated Participants With IDH

Most treated participants with IDH reported taking 1 antihypertensive medication in both urban and rural areas (Figure 5). Even though use of combination therapy increased slightly with age, <5% of the participants received ≥3 drugs across all age groups. Most treated participants with IDH reported taking Western antihypertensive medications (9969 or 98%). Among IDH participants using 2 or fewer classes of medications, calcium channel blockers (42%) were the most frequent class of medication used, followed by angiotensin-converting enzyme inhibitors or angiotensin receptor blockers (20%), and diuretics (7%), respectively (Table 5). On stratification of IDH patients based on their degree of DBP elevation, we found that the majority (74.7%) had DBP of 90 to 95 mm Hg, followed by 96 to 100 mm Hg (19.6%), and >100 mm Hg (5.7%), respectively. The most frequently used antihypertensive medication class and the number of antihypertensive medications used did not vary significantly between 3 groups (both $P>0.05$; Figure S5).

Discussion

In this large study, we report the characteristics, prevalence, awareness, and treatment patterns of people with IDH in China, and how these differ from other hypertensives and vary across diverse population subgroups. We found that IDH affected almost 4% of adults between 35 and 75 years in China (and represents nearly 25% of the hypertensive population aged <45 years). Awareness of hypertension was significantly lower among people with IDH as compared with other types of hypertension and was lowest among young- and middle-aged adults in whom IDH was most prevalent. Additionally, among those with IDH despite treatment, the vast majority were treated with only 1 class of antihypertensive medication.

This study extends the scientific literature in several ways. First, this is one of the largest population-based studies, to our knowledge, to evaluate the characteristics and prevalence of IDH, allowing us to draw robust conclusions across a wide variety of diverse subgroups. Our findings that young age, male sex, obesity, DM, alcohol

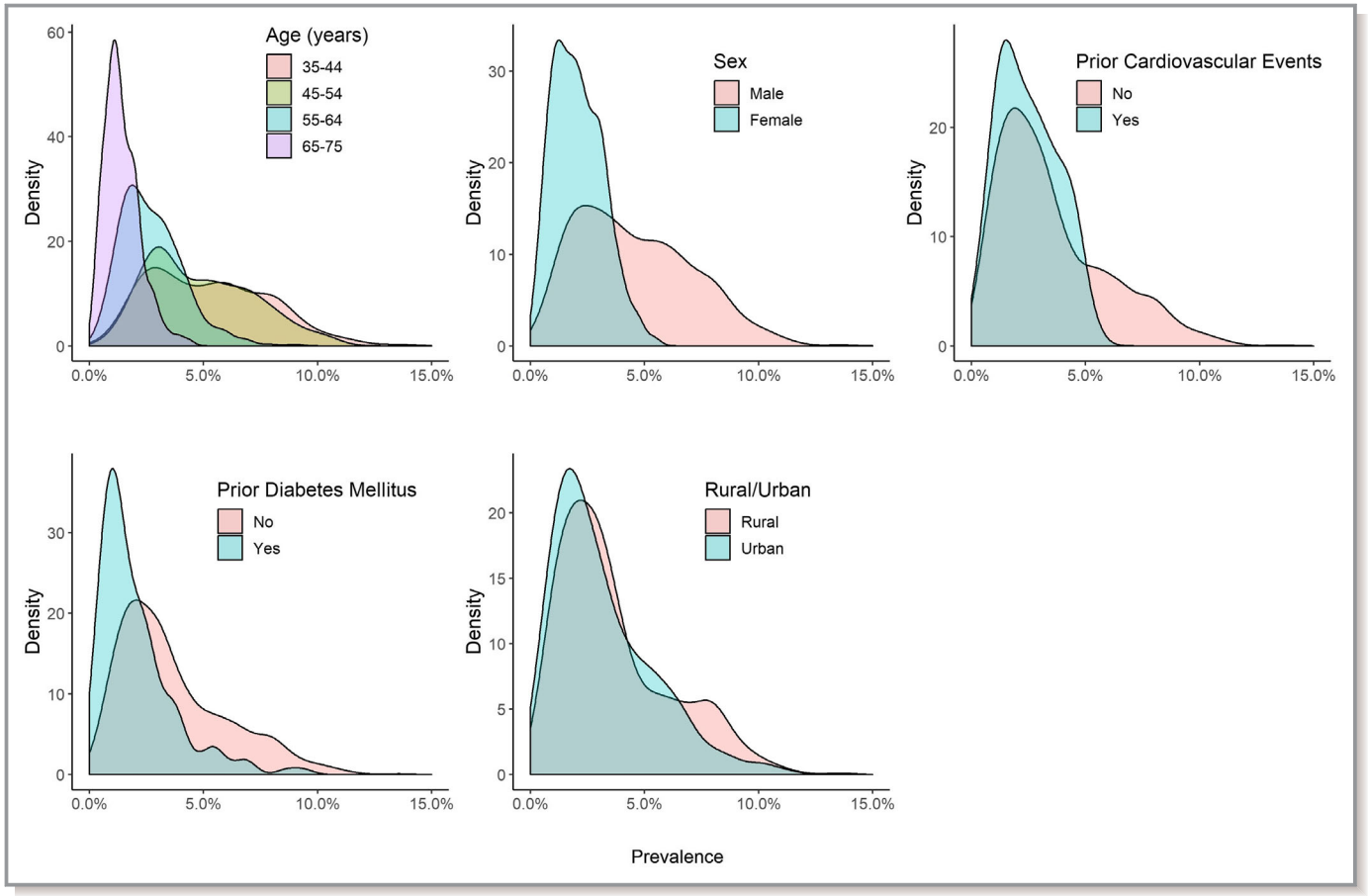

Figure 2. Density plots of prevalence of isolated diastolic hypertension among all study participants in 1198 mutually exclusive population subgroups (of at least 200 participants), by age, sex, prior cardiovascular events, history of diabetes mellitus, and urbanity.

consumption, and prior cardiovascular events are positively associated with IDH prevalence supports and expands on the associations previously described in the literature but with smaller numbers of patients with IDH.[1,3,20,25–27] For example, Franklin et al[20] and Liu et al[25] showed that younger age, male sex, and BMI were predictors of IDH in a small population of IDH patients. In this study, we identified additional factors associated with IDH including DM, alcohol consumption, history of prior cardiovascular event, and showed that these associations were consistent across tens of thousands of individuals with IDH and across diverse population subgroups. The prevalence rates of IDH found in our study were also comparable with those reported previously in studies not only from Chinese cohorts (for example, Huang et al[3] found a prevalence of 4.4% among adults aged 35 to 74 and Sun et al[11] found a prevalence of 5.8% among adults >35 years), but also from other low- and middle-income countries.[26,27]

Second, to the best of our knowledge, our study is the first to assess the awareness of having hypertension among a large Chinese population with IDH compared with other hypertension subtypes, and to identify characteristics that are associated with awareness. Our findings suggest that even though awareness among participants with IDH increases with age, it is significantly lower as compared with awareness among participants with other hypertension subtypes, across all age groups. These findings are consistent with previous reports from other countries which have shown 26% lower diagnosis (hazard ratio 0.74; CI 0.60–0.92) and 31% lower medication initiation (hazard ratio 0.69; CI 0.55–0.86) among younger patients with IDH as compared with systolic/diastolic hypertension.[18]

Third, our assessment of the antihypertensive medications among treated participants with IDH provides information on what medications may not be effectively treating IDH or that people are not taking. We found that the majority of these patients were treated with only 1 class of antihypertensive medication. Calcium channel blockers was the most frequently used class of antihypertensive medication among these patients, even though they may not be most effective for this phenotype, which could be due to the prescription habits of the physicians, availability, and cost-related factors of other classes of antihypertensive medications.[28]

Table 4. Mixed Effects Multivariable Regression Models for Association Between Individual Characteristics and the Prevalence of Isolated Diastolic Hypertension and the Awareness Among Untreated Participants With Isolated Diastolic Hypertension

	Prevalence of IDH				Awareness Among IDH Participants	
	Model 1 Odds Ratio (95% CI)	*P* Value	Model 2 Odds Ratio (95% CI)	*P* Value	Odds Ratio (95% CI)	*P* Value
Age, y						
35 to 39	1		1		1	
40 to 44	1.27 (1.22–1.32)	<0.001	0.81 (0.78–0.84)	<0.001	1.24 (1.08–1.43)	0.003
45 to 49	1.46 (1.41–1.52)	<0.001	0.59 (0.57–0.62)	<0.001	1.65 (1.45–1.88)	<0.001
50 to 54	1.54 (1.48–1.60)	<0.001	0.40 (0.38–0.42)	<0.001	2.13 (1.87–2.43)	<0.001
55 to 59	1.29 (1.25–1.35)	<0.001	0.25 (0.24–0.26)	<0.001	2.37 (2.07–2.72)	<0.001
60 to 64	0.99 (0.95–1.03)	0.534	0.15 (0.14–0.15)	<0.001	2.75 (2.40–3.17)	<0.001
65 to 69	0.79 (0.75–0.83)	<0.001	0.09 (0.09–0.10)	<0.001	3.26 (2.80–3.79)	<0.001
70 to 75	0.64 (0.61–0.68)	<0.001	0.06 (0.06–0.07)	<0.001	3.05 (2.53–3.68)	<0.001
Sex						
Men	1		1		1	
Women	0.45 (0.44–0.45)	<0.001	0.50 (0.49–0.51)	<0.001	1.07 (1.00–1.14)	0.052
Marital status						
Not married	1		1		1	
Married	0.91 (0.88–0.95)	<0.001	1.02 (0.98–1.07)	0.279	0.88 (0.78–1.00)	0.057
Household income, Yuan/y						
<10 000	1		1		1	
10 000 to 50 000	0.97 (0.95–1.00)	0.031	1.01 (0.99–1.04)	0.277	1.04 (0.97–1.13)	0.264
>50 000	0.99 (0.95–1.02)	0.417	1.05 (1.01–1.08)	0.014	1.17 (1.06–1.30)	0.003
Education level						
Lower than college	1		1		1	
College or above	1.08 (1.04–1.11)	<0.001	1.10 (1.07–1.14)	<0.001	1.16 (1.05–1.28)	0.003
Occupation						
Not farmer	1		1		1	
Farmer	0.95 (0.92–0.97)	<0.001	0.92 (0.89–0.94)	<0.001	0.94 (0.87–1.00)	0.066
Health insurance status						
Uninsured	1		1		1	
Insured	1.07 (0.98–1.15)	0.115	1.02 (0.94–1.10)	0.699	0.87 (0.69–1.10)	0.259
CVD risk factor						
Current smoker	0.88 (0.86–0.90)	<0.001	0.96 (0.94–0.99)	0.001	1.02 (0.95–1.09)	0.656
Current drinker	1.38 (1.35–1.41)	<0.001	1.07 (1.04–1.09)	<0.001	1.02 (0.96–1.09)	0.529
Diabetes mellitus	1.05 (1.01–1.09)	0.012	0.63 (0.60–0.65)	<0.001	2.31 (2.09–2.55)	<0.001
Obesity	2.49 (2.44–2.54)	<0.001	0.92 (0.90–0.94)	<0.001	1.50 (1.41–1.59)	<0.001
Prior CVE	1.65 (1.57–1.74)	<0.001	0.80 (0.76–0.84)	<0.001	3.14 (2.75–3.59)	<0.001
Geographic region						
Western	1		1		1	
Eastern	0.91 (0.88–0.95)	<0.001	0.78 (0.75–0.81)	<0.001	1.52 (1.38–1.67)	<0.001
Central	0.97 (0.93–1.01)	0.167	0.82 (0.79–0.86)	<0.001	1.43 (1.30–1.58)	<0.001

Model 1 includes normotensive participants and participants with isolated diastolic hypertension. Model 2 includes participants with isolated diastolic hypertension and participants with other types of hypertension (isolated systolic hypertension, systolic diastolic hypertension, controlled hypertension). CVD indicates cardiovascular disease; CVE, cardiovascular event; IDH, isolated diastolic hypertension; ISH, isolated systolic hypertension; SDH, systolic diastolic hypertension.

Clinical Implications

These findings have important clinical implications as IDH is independently associated with a higher risk of incident heart failure and cardiovascular mortality as compared with normal BP, and BP lowering in patients with IDH has been shown to protect against major vascular events.[29–31] As such, identifying characteristics that may be associated with IDH and understanding the current awareness and treatment patterns

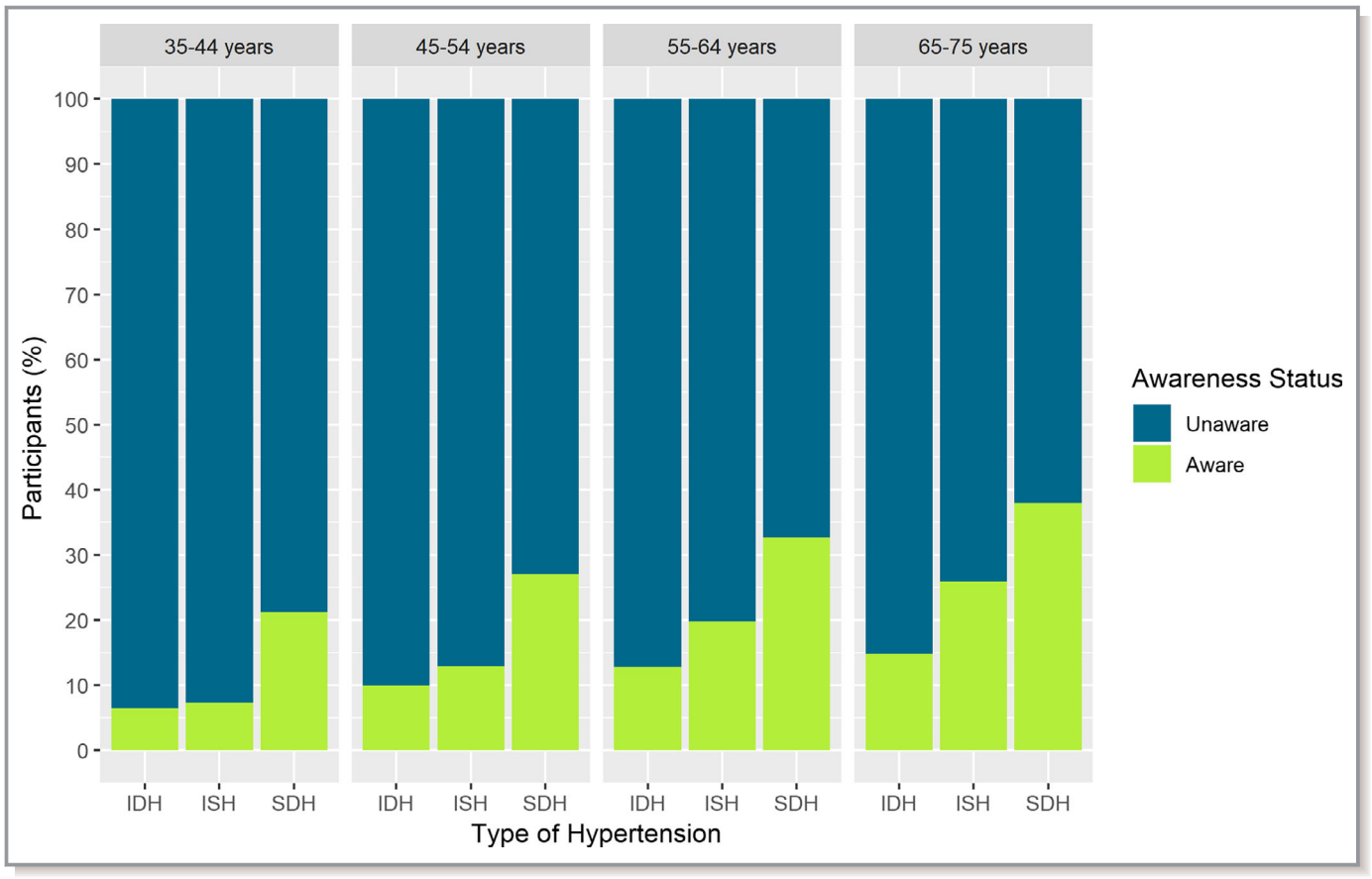

Figure 3. Awareness of having hypertension among untreated participants with isolated diastolic hypertension (IDH), isolated systolic hypertension (ISH), and systolic-diastolic hypertension (SDH), by age group.

among those with IDH can help identify the patients at increased cardiovascular risk and highlight the opportunities for improving their care. Current hypertension management guidelines[15–17] lack guidance on management of patients with IDH and the recent randomized clinical trials[32,33] focused only on SBP targets for improving outcomes, resulting in lack of contemporary guidance on optimal DBP targets for management of patients with IDH. As clinicians and public health professionals develop and implement strategies to help prevent and control hypertension, our findings suggest the need to target people with IDH among other hypertension subtypes for reducing the burden of hypertension.

Considering that patients with IDH are much younger and often without additional cardiovascular risk factors as compared with other hypertension subtypes, they are less likely to come in contact with the health system and hence, more likely to not to be diagnosed. These patients could benefit from more targeted hypertension screening initiatives focusing on the young- and middle-aged adults. For example, promoting free BP screenings at work places and in schools and colleges could result in early diagnosis of those with IDH, and prevent the catastrophic sequelae of hypertension in these patients. Additionally, given the growing burden of obesity in China and its strong association with IDH, it is critical to slow the increase in BMI through public health interventions, to prevent the development of IDH in unaffected individuals. Moreover, increasing awareness of the clinical significance of an elevated DBP in the young and providing clear guidance on management of patients with IDH could also ensure better management of these patients. The point is that the emphasis on SBP should not lead to the neglect of people with IDH.

This study was derived from a large Chinese population. China is of special interest because it represents 25% of the world's population and hypertension is a major public health challenge in China. However, given that China is more recent in the epidemiological transition, and treatment rates are much lower than many Western countries, similar large-scale studies in other countries are warranted to understand impact of nation-specific characteristics on the epidemiology of IDH. Nevertheless, these findings are relevant for several low- and middle-income countries where hypertension is growing in importance, treatment rates tend

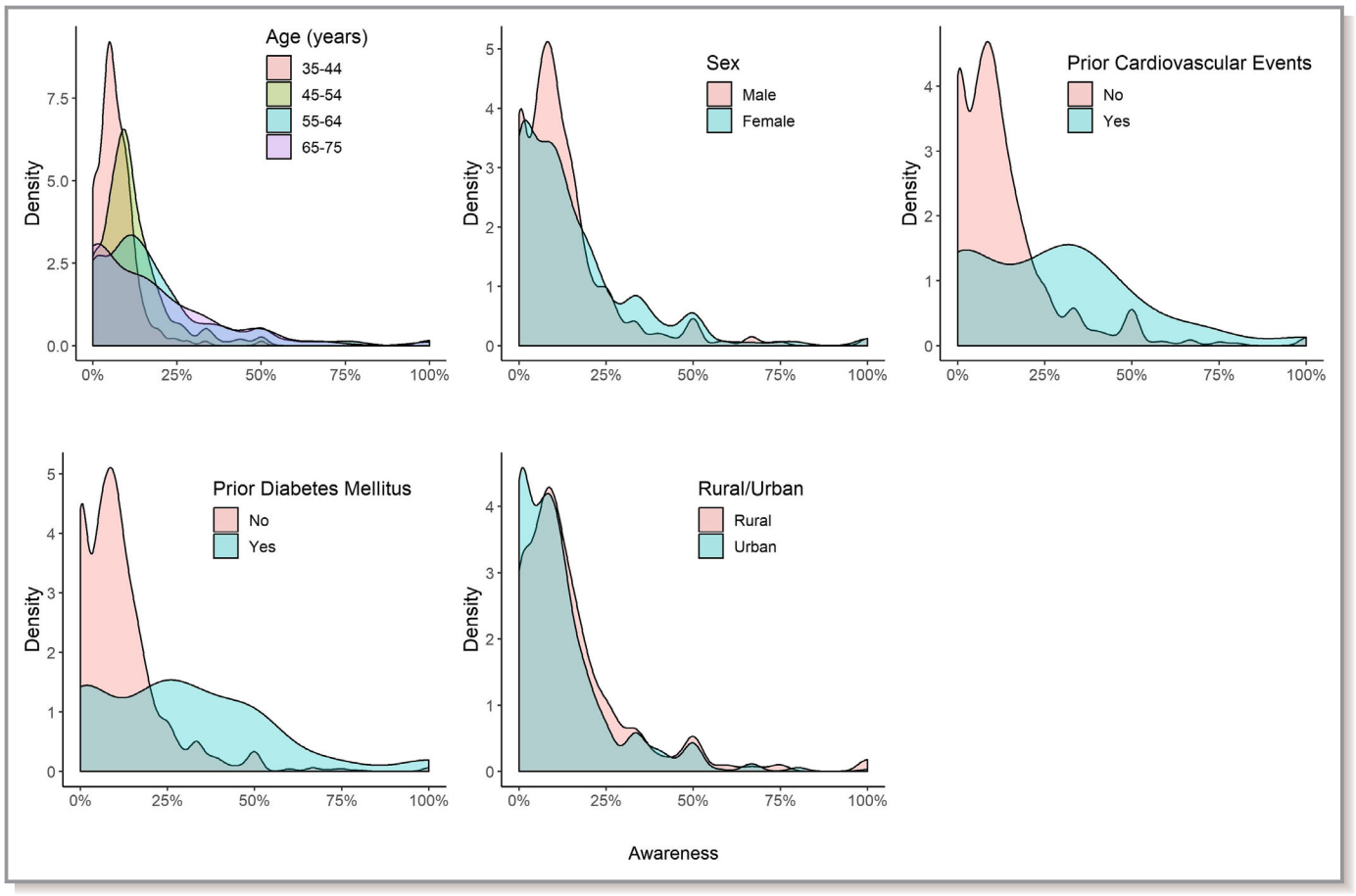

Figure 4. Density plots of awareness of having hypertension among untreated participants with isolated diastolic hypertension in 1198 mutually exclusive population subgroups (of at least 200 participants), by age, sex, prior cardiovascular events, history of diabetes mellitus, and urbanity.

to be lower, and fewer evidence exists to guide public health programs.

Limitations

Our study has several potential limitations. First, for estimation of characteristics and prevalence of participants with IDH, we classified patients into different hypertension subgroups based on the value of the SBP and DBP at enrollment, irrespective of their medication use. As such, some treated hypertensive participants may have had their SBP controlled with medication, and may have been included in the IDH group. However, the vast majority (86%) of the participants in the IDH group were untreated. Moreover, since the treated participants with IDH had persistent elevation of their DBP even after treatment, they were not much different from the untreated IDH group, as shown in Table S1. Second, treated IDH patients who had their DBP <90 mm Hg were classified as having "controlled hypertension" instead of IDH, which could have underestimated the prevalence of IDH of China. However, considering that less than one third of the people with hypertension receive treatment in China and an even fewer proportion actually have controlled hypertension, and that these rates are even lower for younger age groups where IDH is most prevalent,[23] few individuals in the IDH group would have been classified as having "controlled hypertension". Third, our study used convenience rather than a nationally representative sample for large-scale recruitment. This could have resulted in a sampling bias resulting in overestimation of the awareness and treatment rates since these participants would be more likely to be in contact with the health system. Fourth, awareness and treatment rates could also have been affected by a participant's access to and use of healthcare services, however, we did not collect this information in this study. Fifth, since we also used "self-reported use of an antihypertensive medication in the past 2 weeks" as a criterion for defining hypertension, some patients taking hypertensive medication might not have reported that use, possibly underestimating the burden of hypertension in China. Lastly, for individuals who were aware of having hypertension, our study did not collect information on the duration of hypertension, which could have influenced the treatment patterns seen among these participants.

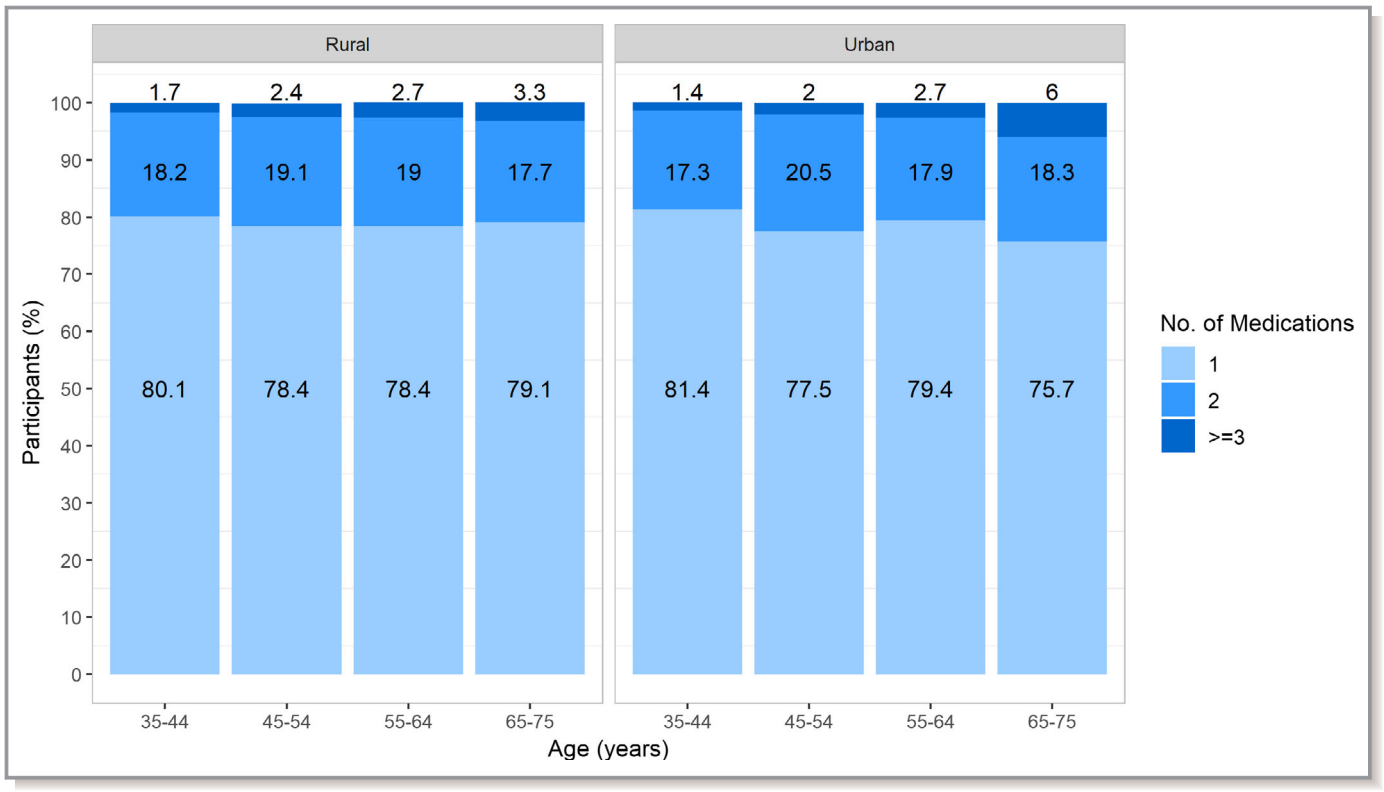

Figure 5. Number of antihypertensive medications used by treated participants with isolated diastolic hypertension, by age and urbanity.

Conclusions

IDH affects a large number of adults in China, and these patients may have some unique characteristics as compared with people without hypertension as well as those with other types of hypertension. However, patients with IDH have the lowest rate of awareness compared with other hypertension subtypes, and most participants with IDH despite treatment had scope for further increase in the intensity of therapy. Our findings suggest the need to specifically focus public health and clinical strategies on people with IDH and improve their diagnosis and treatment, to mitigate the burden of hypertension, especially in the young- and middle-aged population.

Appendix

Members of the Provincial Coordinating Office in China PEACE Million Persons Project

Beijing Center for Diseases Prevention and Control: Chun Huang, Zhong Dong, Bo Jiang; Tianjin Chest Hospital: Zhigang Guo, YingYi Zhang; Hebei Center for Diseases Prevention and Control: Jixin Sun, Yuhuan Liu; Shanxi Center for Diseases

Table 5. Classes of Antihypertensive Medications Used by Treated Participants With Isolated Diastolic Hypertension

	A	B	C	D	F	T
A	1808 (20.08%)	136 (1.51%)	602 (6.69%)	276 (3.07%)	10 (0.11%)	4 (0.04%)
B		331 (3.68%)	224 (2.49%)	27 (0.30%)	13 (0.14%)	3 (0.03%)
C			3780 (41.99%)	71 (0.79%)	43 (0.48%)	14 (0.16%)
D				638 (7.09%)	11 (0.12%)	0 (0%)
F					563 (6.25%)	1 (0.01%)
T						198 (2.20%)

A indicates angiotensin converting enzyme inhibitors or angiotensin receptor blockers; B, beta-blockers; C, calcium channel blockers; D, diuretics; F, fixed-dose combination drugs; T, traditional Chinese medication.

Prevention and Control: Zeping Ren, Yaqing Meng; Inner Mongolia Center for Diseases Prevention and Control: Zhifen Wang, Yunfeng Xi; Liaoning Center for Diseases Prevention and Control: Liying Xing, Yuanmeng Tian; Jilin Center for Diseases Prevention and Control: Jianwei Liu, Yao Fu, Ting Liu; Heilongjiang Center for Diseases Prevention and Control: Wei Sun, Shichun Yan, Lin Jin; Shanghai Center for Diseases Prevention and Control: Yang Zheng, Jing Wang; Jiangsu Center for Diseases Prevention and Control; Zhejiang Provincial People's Hospital: Jing Yan, Xiaoling Xu; Anhui Center for Diseases Prevention and Control: Yeji Chen, Xiuya Xing, Luan Zhang; Fujian Center for Diseases Prevention and Control: Wenling Zhong, Xin Fang; Jiangxi Center for Diseases Prevention and Control: Liping Zhu, Yan Xu; Shandong Center for Diseases Prevention and Control: Xiaolei Guo, Chunxiao Xu; Henan Center for Diseases Prevention and Control: Gang Zhou, Lei Fan, Minjie Qi; Hubei Center for Diseases Prevention and Control: Shuzhen Zhu, Junfeng Qi, Junlin Li; Hunan Center for Diseases Prevention and Control: Li Yin, Qiong Liu; Guangdong Provincial People's Hospital: Qingshan Geng, Yingqing Feng, Jiabin Wang; The First Affiliated Hospital of Guangxi Medical University: Hong Wen; Health Commission of Hainan: Xuemei Han; Hainan Center for Diseases Prevention and Control: Puyu Liu; Chongqing Center for Diseases Prevention and Control: Xianbin Ding, Jie Xu; Sichuan Center for Diseases Prevention and Control: Ying Deng, Jun He; Guizhou Provincial People's Hospital: Gui'e Liu, Chenxi Jiang; Yunnan Center for Diseases Prevention and Control: Shun Zha, Cangjiang Yang; Tibet Center for Diseases Prevention and Control: Guoxia Bai, Yue Yu, Zongji Tashi; Shaanxi Center for Diseases Prevention and Control: Lin Qiu, Zhiping Hu; Gansu Center for Diseases Prevention and Control: Hupeng He, Jing Zhang; Qinghai Center for Diseases Prevention and Control: Minru Zhou, Xiaoping Li; Ningxia Center for Diseases Prevention and Control: Jianhua Zhao, Shaoning Ma; The First Affiliated Hospital of Xinjiang Medical University: Yitong Ma, Ying Huang, Yuchen Zhang; and Xinjiang Corps Center for Diseases Prevention and Control: Fanka Li, Jiacong Shen.

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SUPPLEMENTAL MATERIAL

Data S1.

Supplemental Methods

Equation for the generalized linear mixed effects multivariable regression models used to study the association between individual characteristics and the prevalence of isolated diastolic hypertension and the awareness among untreated participants with isolated diastolic hypertension.

If Y_{ij} indicates that the i^{th} patient in the j^{th} township is hypertensive, then we estimated

$$\text{logit}(\Pr[Y_{ij}=1]) = \alpha_j + \Sigma\, BX_{ij}$$

where $\alpha_j \sim N(0, \tau^2)$ is a random intercept over townships and X_{ij} is a vector of patient risk factors.

We used age, sex, marital status, annual household income, education level, occupation, health insurance status, smoking, alcohol use, obesity, diabetes mellitus, prior cardiovascular events, and geographical region as risk factors.

Table S1. Baseline characteristics of participants with isolated diastolic hypertension, by treatment status.

Characteristics, n (%, 95% CI)	Untreated participants with IDH	Treated participants with IDH
N (%)	63112	10167
Age (years)		
35-39	4361 (6.9%, 6.7 - 7.1)	242 (2.4%, 2.1 - 2.7)
40-44	9658 (15.3%, 15.0 - 15.6)	880 (8.7%, 8.1 - 9.2)
45-49	13,560 (21.5%, 21.2 - 21.8)	1768 (17.4%, 16.7 - 18.1)
50-54	13,939 (22.1%, 21.8 - 22.4)	2540 (25.0%, 24.1 - 25.8)
55-59	8354 (13.2%, 13.0 - 13.5)	1728 (17.0%, 16.3 - 17.7)
60-64	7258 (11.5%, 11.3 - 11.7)	1652 (16.2%, 15.5 - 17.0)
65-69	4062 (6.4%, 6.2 - 6.6)	923 (9.1%, 8.5 - 9.6)
70-75	1920 (3.0%, 2.9 - 3.2)	434 (4.3%, 3.9 - 4.7)
Sex		
Men	36,421 (57.7%, 57.3 - 58.1)	5939 (58.4%, 57.5 - 59.4)
Women	26,691 (42.3%, 41.9 - 42.7)	4228 (41.6%, 40.6 - 42.5)
Urbanity		
Urban	22,345 (35.4%, 35.0 - 35.8)	3964 (39.0%, 38.0 - 39.9)
Rural	40,767 (64.6%, 64.2 - 65.0)	6203 (61.0%, 60.1 - 62.0)
Region		
Eastern	20,374 (32.3%, 31.9 - 32.6)	3528 (34.7%, 33.8 - 35.6)
Western	24,697 (39.1%, 38.8 - 39.5)	3459 (34.0%, 33.1 - 34.9)
Central	18,041 (28.6%, 28.2 - 28.9)	3180 (31.3%, 30.4 - 32.2)
Education		
Primary school or lower	23,063 (36.5%, 36.2 - 36.9)	3149 (31.0%, 30.1 - 31.9)
Middle school	22,377 (35.5%, 35.1 - 35.8)	3582 (35.2%, 34.3 - 36.2)
High school	10,333 (16.4%, 16.1 - 16.7)	2035 (20.0%, 19.2 - 20.8)
College or above	6314 (10.0%, 9.8 - 10.2)	1288 (12.7%, 12.0 - 13.3)
Unknown*	1025 (1.6%, 1.5 - 1.7)	113 (1.1%, 0.9 - 1.3)
Employment		
Employed	50,534 (80.1%, 79.8 - 80.4)	7048 (69.3%, 68.4 - 70.2)
Unemployed	1109 (1.8%, 1.7 - 1.9)	236 (2.3%, 2.0 - 2.6)
Retired	6351 (10.1%, 9.8 - 10.3)	1991 (19.6%, 18.8 - 20.4)
Housework	3761 (6.0%, 5.8 - 6.1)	709 (7.0%, 6.5 - 7.5)
Unknown*	1357 (2.2%, 2.0 - 2.3)	183 (1.8%, 1.5 - 2.1)
Occupation		
Famer	30,616 (48.5%, 48.1 - 48.9)	3946 (38.8%, 37.9 - 39.8)
Nonfarmer	31,139 (49.3%, 48.9 - 49.7)	6038 (59.4%, 58.4 - 60.3)

Unknown*	1357 (2.2%, 2.0 - 2.3)	183 (1.8%, 1.5 - 2.1)
Household Income (Yuan/year)		
< 10,000	12,725 (20.2%, 19.8 - 20.5)	1582 (15.6%, 14.9 - 16.3)
10,000-50,000	34,601 (54.8%, 54.4 - 55.2)	5758 (56.6%, 55.7 - 57.6)
> 50,000	9903 (15.7%, 15.4 - 16.0)	2005 (19.7%, 18.9 - 20.5)
Unknown*	5883 (9.3%, 9.1 - 9.5)	822 (8.1%, 7.6 - 8.6)
Marital Status		
Married	59,671 (94.5%, 94.4 - 94.7)	9488 (93.3%, 92.8 - 93.8)
Widowed, separated, divorced, single	2629 (4.2%, 4.0 - 4.3)	563 (5.5%, 5.1 - 6.0)
Unknown*	812 (1.3%, 1.2 - 1.4)	116 (1.1%, 0.9 - 1.3)
Health Insurance Status		
Insured	61,637 (97.7%, 97.5 - 97.8)	9943 (97.8%, 97.5 - 98.1)
Uninsured	448 (0.7%, 0.6 - 0.8)	54 (0.5%, 0.4 - 0.7)
Unknown*	1027 (1.6%, 1.5 - 1.7)	170 (1.7%, 1.4 - 1.9)
Medical History		
Myocardial Infarction	334 (0.5%, 0.5 - 0.6)	162 (1.6%, 1.3 - 1.8)
Stroke	986 (1.6%, 1.5 - 1.7)	628 (6.2%, 5.7 - 6.6)
Diabetes Mellitus	2521 (4.0%, 3.8 - 4.1)	978 (9.6%, 9.0 - 10.2)
CVD Risk Factor		
Current smoker	17,842 (28.3%, 27.9 - 28.6)	2825 (27.8%, 26.9 - 28.7)
Current drinker	22,740 (36.0%, 35.7 - 36.4)	3789 (37.3%, 36.3 - 38.2)
Obesity	13,970 (22.1%, 21.8 - 22.5)	3271 (32.2%, 31.3 - 33.1)

CI, Confidence Interval; CVD, Cardiovascular Disease; IDH, Isolated Diastolic Hypertension

* Participants either refused to answer the question or did not know the answer.

Table S2. Prevalence of isolated diastolic hypertension among treated hypertensive participants, by population characteristics.

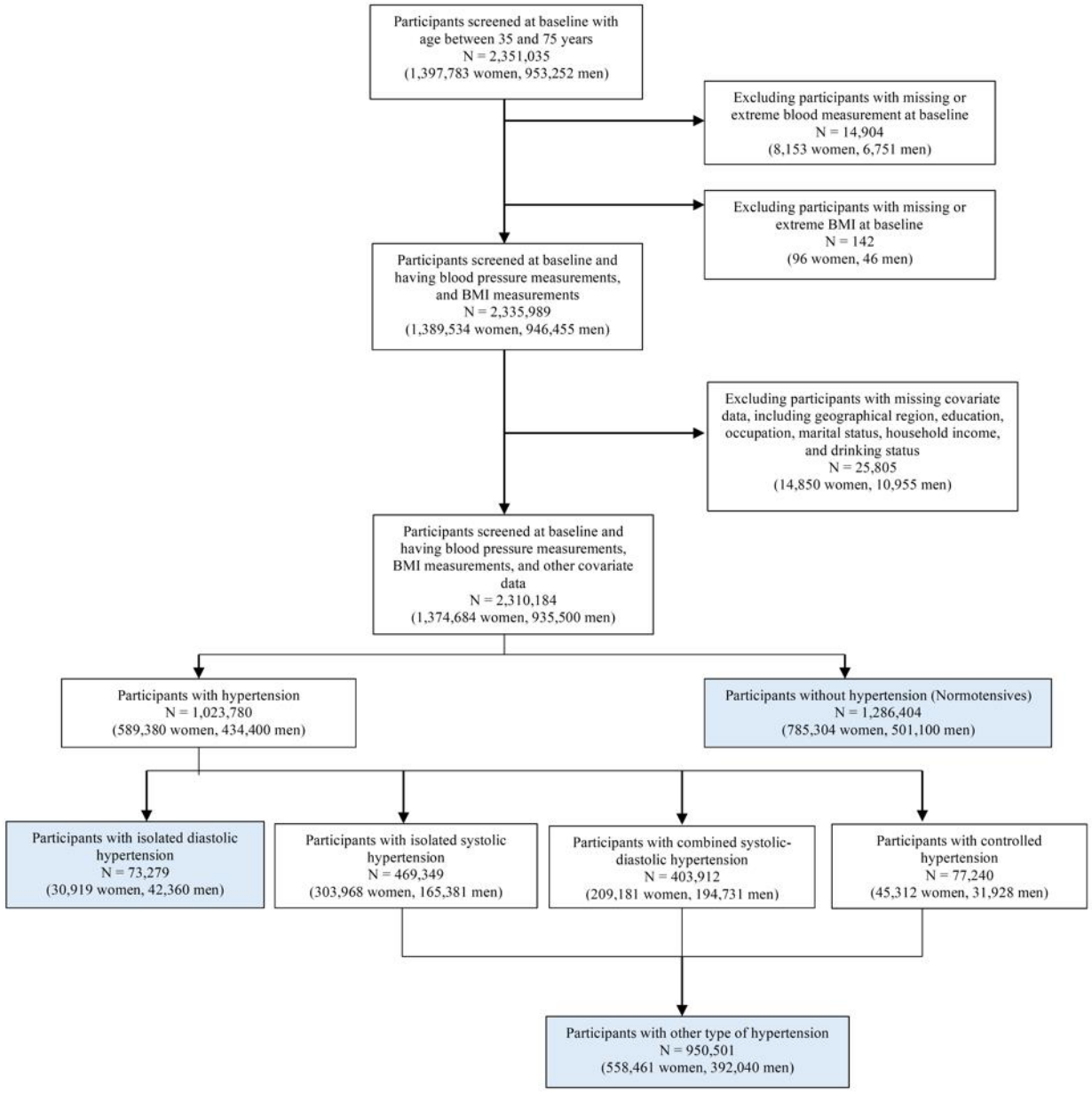
Characteristics, n (%, 95% CI)	Treated Hypertensives	Prevalence of IDH
N (%)	305,114	10,167 (3.3%, 3.3 - 3.4)
Age (years)		
35-39	2234	242 (10.8%, 9.5 - 12.1)
40-44	8621	880 (10.2%, 9.6 - 10.8)
45-49	22,341	1768 (7.9%, 7.6 - 8.3)
50-54	44,989	2540 (5.6%, 5.4 - 5.9)
55-59	48,750	1728 (3.5%, 3.4 - 3.7)
60-64	70,373	1652 (2.3%, 2.2 - 2.5)
65-69	63,575	923 (1.5%, 1.4 - 1.5)
70-75	44,231	434 (1.0%, 0.9 - 1.1)
Sex		
Men	122,604	5939 (4.8%, 4.7 - 5.0)
Women	182,510	4228 (2.3%, 2.2 - 2.4)
Urbanity		
Urban	121,796	3964 (3.3%, 3.2 - 3.4)
Rural	183,318	6203 (3.4%, 3.3 - 3.5)
Region		
Eastern	117,526	3528 (3.0%, 2.9 - 3.1)
Western	96,020	3459 (3.6%, 3.5 - 3.7)
Central	91,568	3180 (3.5%, 3.4 - 3.6)
Education		
Primary school or lower	141,784	3149 (2.2%, 2.1 - 2.3)
Middle school	94,633	3582 (3.8%, 3.7 - 3.9)
High school	46,285	2035 (4.4%, 4.2 - 4.6)
College or above	19,279	1288 (6.7%, 6.3 - 7.0)
Unknown*	3133	113 (3.6%, 3.0 - 4.3)
Employment		
Employed	184,078	7048 (3.8%, 3.7 - 3.9)
Unemployed	4236	236 (5.6%, 4.9 - 6.3)
Retired	83,825	1991 (2.4%, 2.3 - 2.5)
Housework	28,919	709 (2.5%, 2.3 - 2.6)
Unknown*	4056	183 (4.5%, 3.9 - 5.2)
Occupation		
Famer	139,046	3946 (2.8%, 2.8 - 2.9)
Nonfarmer	162,012	6038 (3.7%, 3.6 - 3.8)
Unknown*	4056	183 (4.5%, 3.9 - 5.2)

Household Income (Yuan/year)		
< 10,000	62,445	1582 (2.5%, 2.4 - 2.7)
10,000-50,000	171,760	5758 (3.4%, 3.3 - 3.4)
> 50,000	48,107	2005 (4.2%, 4.0 - 4.3)
Unknown*	22,802	822 (3.6%, 3.4 - 3.8)
Marital Status		
Married	276,287	9488 (3.4%, 3.4 - 3.5)
Widowed, separated, divorced, single	25,708	563 (2.2%, 2.0 - 2.4)
Unknown*	3119	116 (3.7%, 3.1 - 4.4)
Health Insurance Status		
Insured	299,640	9943 (3.3%, 3.3 - 3.4)
Uninsured	1262	54 (4.3%, 3.2 - 5.4)
Unknown*	4212	170 (4.0%, 3.4 - 4.6)
Medical History		
Myocardial Infarction	5776	162 (2.8%, 2.4 - 3.2)
Stroke	21,343	628 (2.9%, 2.7 - 3.2)
Diabetes Mellitus	45,532	978 (2.1%, 2.0 - 2.3)
CVD Risk Factor		
Current smoker	56,473	2825 (5.0%, 4.8 - 5.2)
Current drinker	72,935	3789 (5.2%, 5.0 - 5.4)
Obesity	84,843	3271 (3.9%, 3.7 - 4.0)

CI, Confidence Interval; CVD, Cardiovascular Disease; IDH, Isolated Diastolic Hypertension

* Participants either refused to answer the question or did not know the answer.

Figure S1. Flowchart of study participant selection in China Patient-Centered Evaluative Assessment of Cardiac Events Million Persons Project.



BMI, Body Mass Index

Figure S2. Histograms of prevalence of isolated diastolic hypertension (IDH) and awareness among untreated IDH participants in 1,198 mutually exclusive population subgroups (at least 200 participants each) defined priori by 10 selected characteristics.

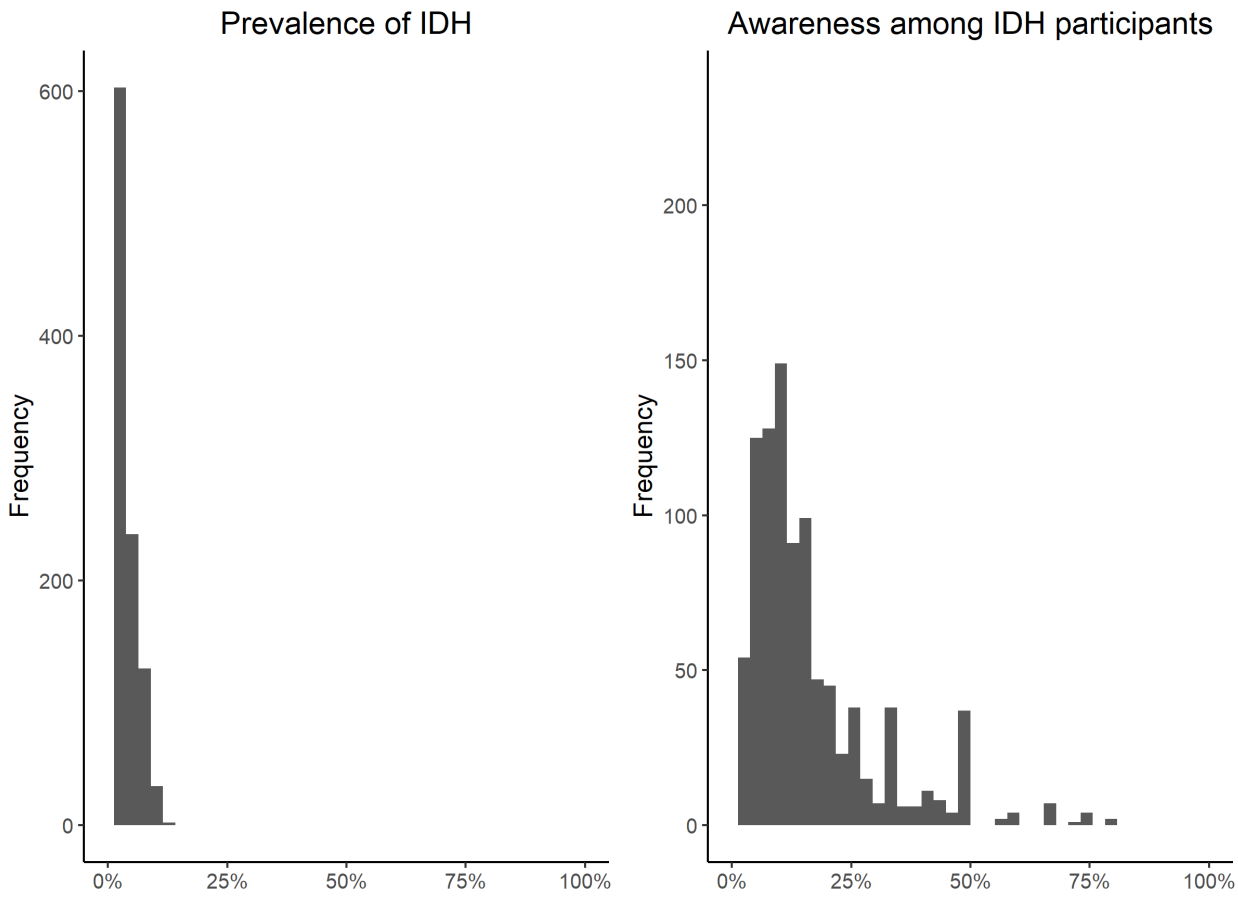


Figure S3. Histograms prevalence of isolated diastolic hypertension (IDH) and awareness among untreated IDH participants in 731 mutually exclusive population subgroups (at least 500 participants each) defined priori by 10 selected characteristics.

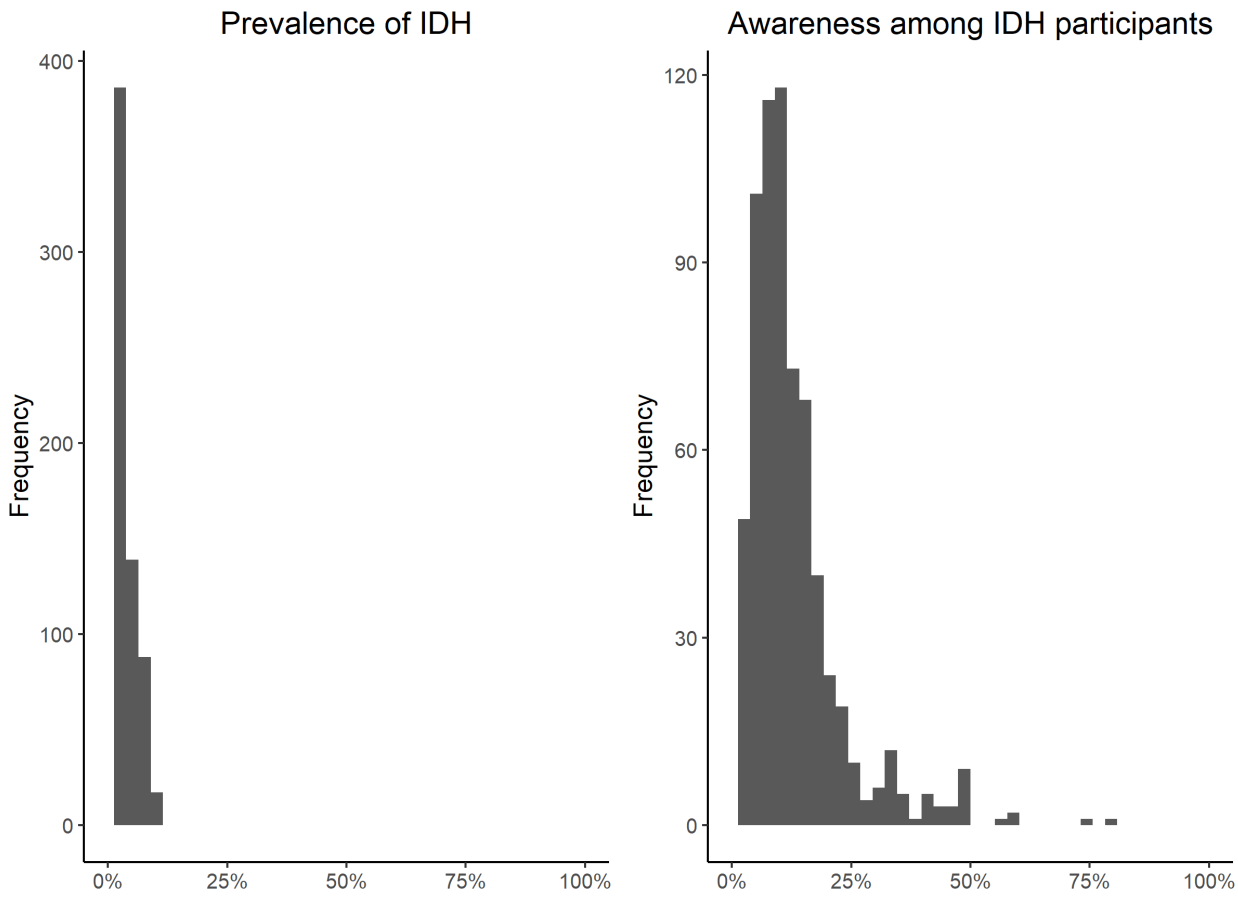
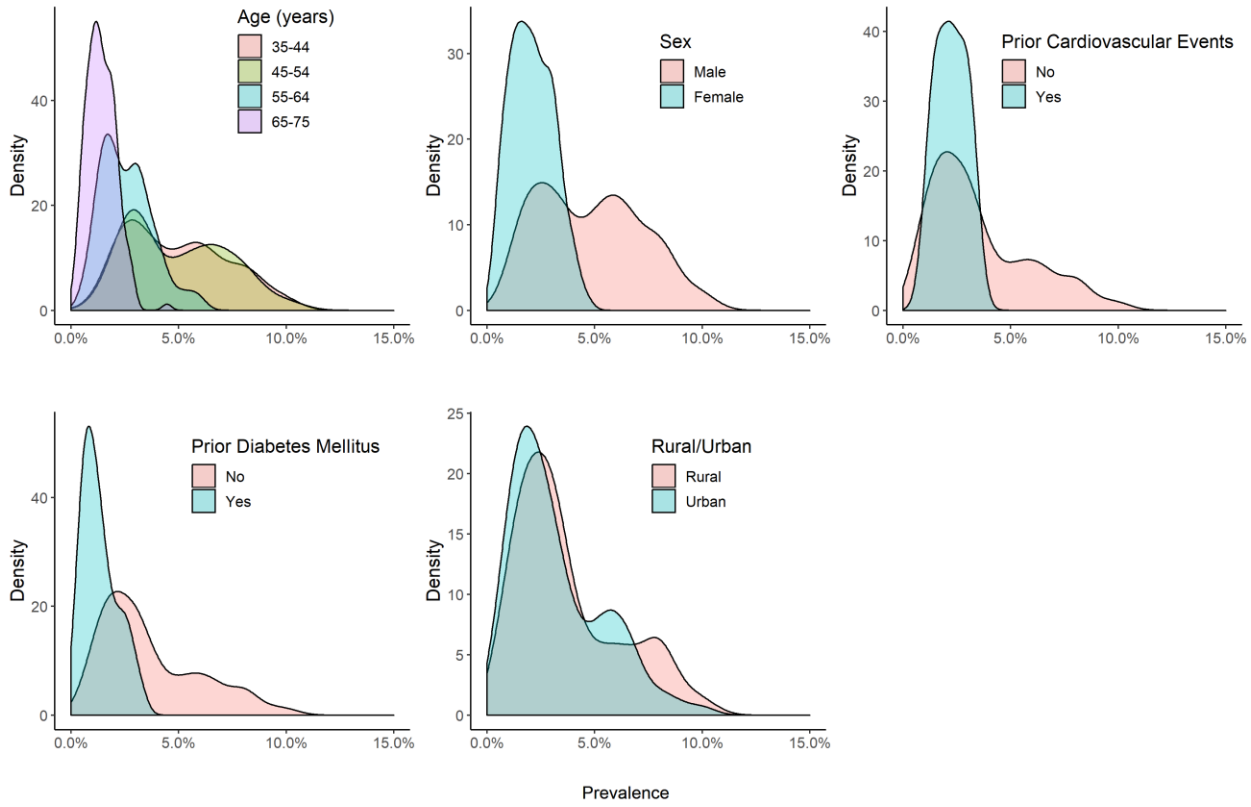


Figure S4. Density plots of prevalence of isolated diastolic hypertension (IDH) among all study participants (A) and awareness among untreated IDH participants (B) in 731 mutually exclusive population subgroups (of at least 500 participants), by age, sex, prior cardiovascular events, history of diabetes and urbanity.

A. Prevalence



B. Awareness

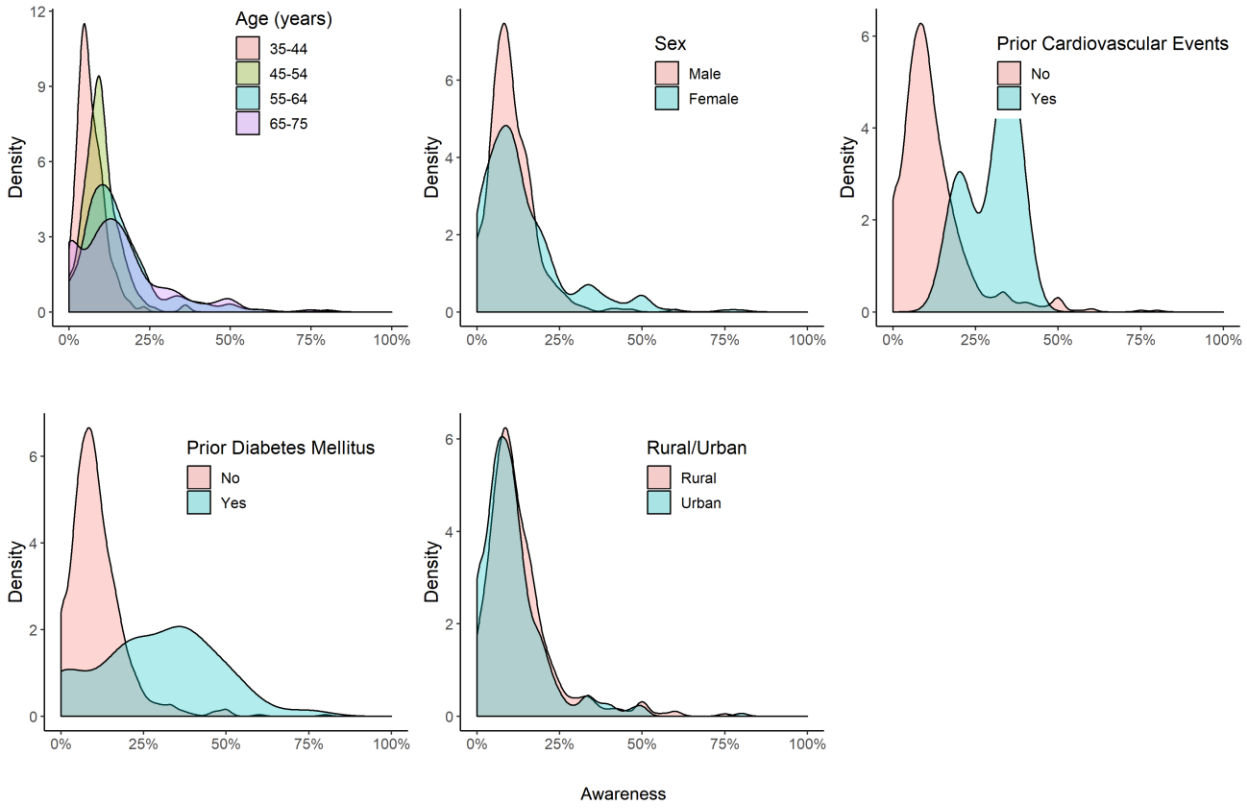

Age (years)
35-44
45-54
55-64
65-75
Sex
Male
Female
Prior Cardiovascular Events
No
Yes
Prior Diabetes Mellitus
No
Yes
Rural/Urban
Rural
Urban
Density
Awareness
0%
25%
50%
75%
100%

Figure S5. Number of antihypertensive medications used by treated participants with isolated diastolic hypertension, by degree of diastolic blood pressure (DBP) elevation.