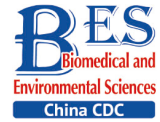


Letter to the Editor



Incidence and Risk Factors of Progression from Prehypertension or Hypertension to Diabetes among Older Adults of Northeastern China: A Prospective Cohort Study*

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Approximately two-thirds of patients with type 2 diabetes have hypertension. Moreover, blood pressure (BP) increases with hyperglycemia progression. The nexus between prehypertension or hypertension and diabetes entails pathophysiological mechanisms, such as the involvement of the nitric-oxide pathway in insulin resistance and the contribution of hyperinsulinemia to sympathetic activity, sodium-fluid retention, and renin-angiotensin-aldosterone system activation^[1]. Thus, prehypertension or hypertension is related to diabetes.

Prehypertension is a novel BP category from the seventh report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High BP^[2]. Prehypertension is reported in > 30% of Americans^[3]. Population^[2] with prehypertension has been increasing with development in China^[4]. Prehypertension increases the risks of diabetes mellitus in adults aged 25–49 years but not in those aged 50–65 years^[5]. Hypertension functions as a risk factor for diabetes mellitus^[6]. Importantly, separating the incidence rate of diabetes mellitus in the prehypertensive population from that in the hypertensive population provides new perspectives on the relationship between prehypertension/hypertension and diabetes because the incidence rate reflects epidemic intensity. However, the difference between the incidence rate of diabetes mellitus in the prehypertensive population and that in the hypertensive population is unknown, and connections between antihypertensive medication and diabetes mellitus in the hypertensive population remain conflicting. Importantly, revealing the discrepancies in the risk factors of diabetes in prehypertensive and hypertensive populations holds

great value for adopting more specific management modes. Thus, this study aimed to compare the difference between the incidence rates, investigate the risk factors of diabetes in hypertensive and prehypertensive populations, document the connections between antihypertensive medication and diabetes mellitus, and assess the effect of government intervention on these populations based on a prospective cohort in Northeast China.

We utilized data from Changchun city in the first (2019–2020) and second surveys (2021–2022) on the prevention and control of major chronic non-communicable diseases in Northeast China. Data were collected through a face-to-face survey by investigators in 10 community health centers that were randomly selected from 12 centers. The first survey included a multicenter cohort with 11,122 participants. We enrolled participants according to the following inclusion criteria: 1) over the age of 60 years; 2) officially registered residents; 3) living in Changchun for > 6 months; 4) with consciousness and no communication barriers; 5) with follow-up data; 6) without diabetes. Finally, 3,151 participants were eligible for further analysis ([Supplementary Figure S1](#), available in www.besjournal.com).

Prehypertension was defined as systolic blood pressure (SBP) (120–139 mmHg) or diastolic blood pressure (DBP) (80–89 mmHg), and hypertension was defined as SBP (\geq 140 mmHg) or DBP (\geq 90 mmHg) or with antihypertensive medication^[2]. Participants with diabetes mellitus were defined as those with \geq 7 mmol/L of fasting plasma glucose, current use of anti-diabetic medication, or a history of diabetes mellitus. Normoglycemia was defined as < 5.6 mmol/L of fasting blood glucose, and impaired fasting glucose (IFG) was defined as a fasting blood

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glucose concentration between 5.6 and 6.9 mmol/L^[7]. Body mass index (BMI) was calculated as body weight (in kg) divided by the square of height (in meters) to identify whether participants were underweight (BMI < 18.5), normal (BMI = 18.5–24.0), overweight (BMI = 24.0–28.0), and obese (BMI ≥ 28.0). Dyslipidemia was defined as ≥ 2.26 mmol/L of total triglyceride (TG), ≥ 6.22 mmol/L of total cholesterol (TC), ≥ 4.14 mmol/L of low-density lipoprotein cholesterol (LDL-C), or < 1.04 mmol/L of high-density lipoprotein cholesterol (HDL-C)^[8]. Current drinking was defined as drinking alcohol (beer, wine, or white spirit) at least three times a week for > 6 months. Current smoking was defined as smoking at least one cigarette per day for > 6 months. Physical exercise was defined as never, sometimes (1–2 days in a week or month), or often (almost every day or 3–4 days a week) with one of the flexible, aerobic, or anaerobic exercises. Antihypertensive medication was defined as currently taking antihypertensive medications in patients with hypertension.

Continuous variables were expressed as mean ± standard deviation. Categorical variables were expressed as numbers (%) and were compared using the chi-square test for trend or the chi-squared test. Risk ratios (RR) and 95% confidence intervals (CIs) were calculated using the Poisson regression model modified by a sandwich variance estimator. The multivariate logistic regression model was performed to analyze RR and 95% CIs based on stepwise selection for potential risk factors identified from the univariate analyses and visualized using nomograms. The receiver operating characteristic (ROC) curve and Harrell's concordance index (C-index) were used to evaluate the performance of the multivariate logistic regression model. All data analyses were performed by SPSS version 26 (Inc., Chicago, IL, USA) and R version 4.1.0, and *P*-values of < 0.05 were considered statistically significant.

This study enrolled 3,151 elderly participants with elevated BP (1,177 males and 1,974 females)

aged from 60 to 100 years, thereby finding 1,477 with prehypertension and 1,674 with hypertension. Elderly females were prone to hypertension. Hypertensive participants accounted for high proportions in the following items compared with prehypertensive participants: overweight or obese; divorced or separated or widowed; junior and middle school or below; an annual income of less than ¥30,000; with high levels of TG, HDL-C, and fasting plasma glucose (FPG); with history of coronary heart disease; and with a family history of hypertension or coronary heart disease (Supplementary Table S1, available in www.besjournal.com).

This study revealed that 7.1% (224) of the nondiabetic participants with prehypertension or hypertension in the initial survey were the ones with diabetes after 2 years. The incidence rate of diabetes in the participants with hypertension was significantly higher than that in the participants with prehypertension (RR = 1.308, 95% CI: 1.006–1.707, *P* = 0.045) (Table 1).

Significant differences were found between the diabetic and nondiabetic participants in BMI, coronary heart disease history, family history of diabetes and coronary heart disease, TG, and FPG (all *P* < 0.05) (Supplementary Table S2, available in www.besjournal.com). Then, we identified that BMI, family history of diabetes, and FPG were all significantly associated with the occurrence of diabetes using multivariate logistic regression (Supplementary Table S3, available in www.besjournal.com). Compared with patient with obesity, normal and overweight patients had low risks of diabetes (normal: RR = 0.542, 95% CI: 0.348–0.742; overweight: RR = 0.677, 95% CI: 0.462–0.946). Compared with normal FPG, IFG was a strong predictor of diabetes (RR = 2.130, 95% CI: 1.613–2.812). Additionally, a family history of diabetes was a high-risk factor for diabetes (RR = 2.788, 95% CI: 1.143–6.798).

Univariate analysis revealed a significant

Table 1. Association between prehypertension and hypertension at baseline and diabetes, estimated by poisson regression

Group	Total (n = 3,151)	Diabetes (n = 224), n (%)	1,000 person-years	Adjusted RR (n = 168), n (%)	<i>P</i> value
Prehypertension	1,477	84 (5.7)	28.44	1	
Hypertension	1,674	140 (8.4)	41.82	1.308 (1.006, 1.707)	0.045

Note. 1: the reference cell. Final model adjusted for age, sex, education level, marital status, annual income, ethnicity, smoking, drinking, physical activity, BMI, stroke, coronary heart disease, family history of hypertension, stroke, diabetes, coronary heart disease, TG, TC, HDL-C, LDL-C, and FPG.

association between the occurrence of diabetes in the prehypertensive participants and the elevated FPG and TC and between the hypertensive participants and FPG, TG, BMI, family history of diabetes, family history of coronary heart disease, self-management, and community management (all $P < 0.05$) (Supplementary Table S4, available in www.besjournal.com).

Multivariate logistic regression identified that the occurrence of diabetes in the participants with prehypertension was associated with BMI, physical exercise, TC, and FPG; and the occurrence of diabetes in the participants with hypertension was associated with BMI, physical exercise, TG, FPG, family history of diabetes, and community management (Tables 2–3).

Interestingly, we discerned the effect of physical exercise on diabetes, finding a paradox that frequent physical exercise was a protective factor for diabetes in participants with prehypertension, while seldom physical exercise was a protective factor for diabetes in participants with hypertension. Physical exercise influences diabetes and hypertension *via* regulating metabolism; however, the effects of physical exercise on prehypertension have not been discerned from those on hypertension. Indeed, we revealed different effects of physical exercise between the participants with prehypertension and hypertension: “frequent” was a protective factor for

prehypertensive participants, and “seldom” was a protective factor for hypertensive participants. Hypertension and endothelial dysfunctions are linked to an insulin-resistant state, thereby promoting the occurrence of type 2 diabetes mellitus. Physical exercise induces the intracellular production of NO* by enhancing the flux of muscle- and kidney-derived amino acids to pancreatic and vascular endothelial cells, resulting in the normalization of insulin secretion, vascular tone, and insulin sensitivity. Additionally, physical exercise impacts angiotensin II and asymmetric dimethylarginine signaling, thereby triggering the production of anti-inflammatory cytokines in muscle and reducing the progression and development of vascular disease and diabetes^[9].

Reduced vascular impairments were observed more in participants with prehypertension than in participants with hypertension. This difference in the beneficial effects is derived from physical exercise in the improvement of metabolic and cardiovascular health. However, physical exercise is unable to balance increased vascular impairments in participants with hypertension. We attribute “seldom physical exercise” as a protective factor for diabetes in participants with hypertension to the smaller sample size.

Metabolic syndrome is one of the states of prediabetes, and individuals with metabolic

Table 2. Multivariate analysis for the risk factors associated with progression to diabetes in participants with prehypertension

Characteristics	P value	RR	95% CI
Body mass index (BMI)			
Underweight	0.196	0.255	0.032–2.024
Normal	0.037	0.511	0.272–0.959
Overweight	0.114	0.601	0.320–1.130
Obese	0.163	1	
Physical exercise			
Never	0.008	1	
Sometimes	0.718	1.189	0.464–3.046
Often	0.005	0.498	0.306–0.811
Total cholesterol (mmol/L)			
< 6.2		1	
≥ 6.2	0.020	1.876	1.103–3.191
Fasting plasma glucose (mmol/L)			
< 5.6 (normal)		1	
5.6–6.9 (IFG)	0.014	1.772	1.125–2.790

Note. IFG: impaired fasting glucose.

Table 3. Multivariate analysis for the risk factors associated with progression to diabetes in participants with hypertension

Characteristics	P value	RR	95% CI
Body mass index (BMI)			
Underweight	0.955	0.963	0.262–3.543
Normal	0.003	0.470	0.287–0.769
Overweight	0.052	0.642	0.410–1.004
Obese	0.024	1	
Physical exercise			
Never	0.018	1	
Sometimes	0.030	0.107	0.014–0.807
Often	0.163	1.388	0.875–2.200
Family history of diabetes			
Yes	0.048	3.544	1.010–12.435
No		1	
Family history of coronary heart disease			
Yes	0.227	1.683	0.723–3.919
No		1	
Triglyceride (mmol/L)			
< 2.3		1	
≥ 2.3	0.032	1.576	1.039–2.391
Fasting plasma glucose (mmol/L)			
< 5.6 (normal)		1	
5.6–6.9 (IFG)	< 0.001	2.183	1.515–3.147
Self-management			
Regular medication	0.655	1.172	0.584–2.354
Improving diet	0.991	0.996	0.495–2.004
Controlling salt intake	0.334	0.668	0.295–1.514
Increasing exercise	0.106	1.888	0.873–4.083
Combination of self-management			
No	0.121	1	
Single self-management	0.274	1.586	0.694–3.621
2 combinations	0.111	2.197	0.834–5.786
≥ 3 combinations	0.963	1.017	0.497–2.082
Community-management			
BP measurement	< 0.001	0.462	0.313–0.682
Medication guidance	0.205	3.822	0.480–30.419
Dietary guidance	0.674	1.786	0.120–26.609
Physical exercise guidance	0.616	1.691	0.217–13.185
Combination of community-management			
No	0.017	1	
Single management	0.999	0.000	
2 combinations	0.998	0.000	
≥ 3 combinations	0.001	0.509	0.345–0.750

Note. BP: blood pressure; IFG: impaired fasting glucose; 1: the reference cell.

syndrome without diabetes are at significant risk of developing diabetes. This study revealed that those simultaneously with hypertension and metabolic syndrome accounted for a significantly high proportion and had an increased tendency from non-diabetes to diabetes compared with the participants with simultaneous prehypertension and metabolic syndrome (Supplementary Table S5, available in www.besjournal.com). At present, waist circumference, dyslipidemia (TG high and HDL-C low), BP values, and FPG are defined as metabolic syndrome criteria globally. However, we only confirmed that the high FPG criterion was significantly associated with the occurrence of diabetes both in participants with prehypertension and hypertension, thereby providing a new dimension to further crystallize the definition of metabolic syndrome by adding BMI as a new essential criterion.

Further, we investigated the potential effect of two modes of management on diabetes (community and self management) because participants with hypertension received self and community management. We identified that three or more combinations of measures from community management conferred protective effects on diabetes ($RR = 0.509$, 95% CI : 0.345–0.750). BP measurement was the strongest protective factor for diabetes among measures from community management compared with other measures (Table 3). Regular BP measurement dynamically monitors the BP level of participants, thereby helping participants to recognize their own BP status and train healthy behaviors, such as controlling diet and taking antihypertensive drugs to control BP, thereby reducing the risk of diabetes.

We constructed nomograms and ROC curves that document the optimal cutoff values (OCV) of ROC curves and C-indices to provide effective and reliable guides for diabetes prevention [for participants with prehypertension and hypertension, $OCV = -2.161$, C-indices = 0.633 (Supplementary Figure S2, available in www.besjournal.com); for participants with prehypertension, $OCV = -2.838$, C-indices = 0.638 (Supplementary Figure S3, available in www.besjournal.com); for participants with hypertension, $OCV = -2.527$, C-indices = 0.708 (Supplementary Figure S4, available in www.besjournal.com)].

Of the 1,674 participants with hypertension, 140 had developed diabetes after 2 years, of whom 84 did not take antihypertensive medication. Antihypertensive medication decreased the tendency from non-diabetes to diabetes ($RR = 0.704$,

95% CI : 0.504–0.983, $P = 0.039$) (Supplementary Table S6, available in www.besjournal.com).

This study documented that the risks of diabetes in the participants with hypertension are significantly higher than those in the prehypertensive ones, indicating the connection between antihypertensive medication and decreased tendency from non-diabetes to diabetes in participants with hypertension. This study had limitations. Firstly, the participants were only classified according to baseline data of initial enrollment. Secondly, we failed to explore the potential impact of different types of antihypertensive medications on diabetes.

Availability of Data and Materials The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

Ethics Approval and Consent to Participate This project was approved by the Ethics Committee of China Medical University. Each participant provided informed consent.

Consent for Publication Not applicable.

Competing Interests All authors: no conflicts of interest to disclose.

Authors' Contributions Conception and design: LIANG Zhuo Shuai, SHI Ji Kang, CHENG Yi, and LIU Ya Wen. Collection and assembly of data: LIANG Zhuo Shuai, SHI Ji Kang, REN Ya Xuan. Data analysis and interpretation: TIAN Yu Yang, HU Xin Meng, LIU Sai Nan, WANG Yu Jian. Manuscript writing: LIANG Zhuo Shuai. Revised the language/article: All authors. Final approval of manuscript: All authors.

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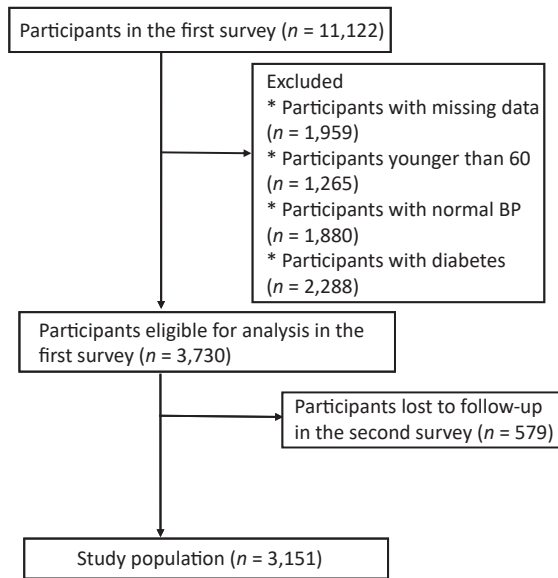
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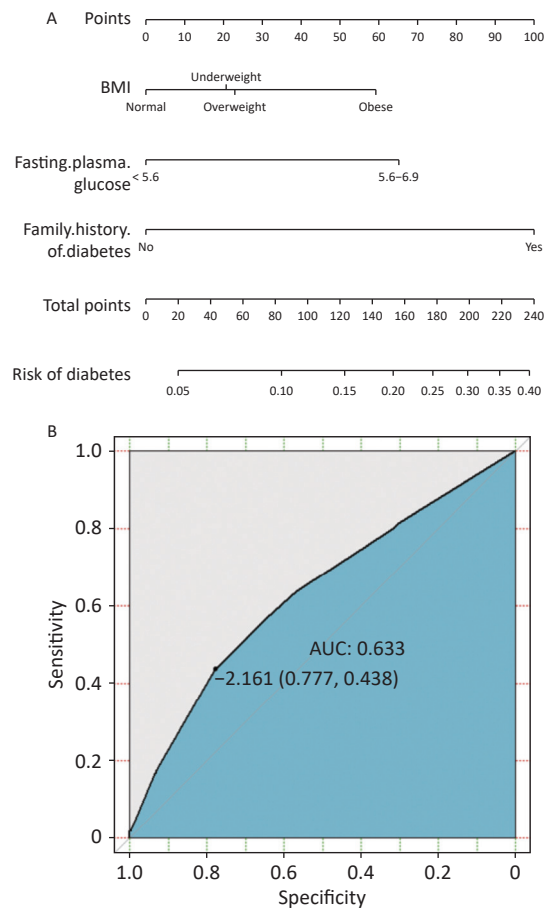
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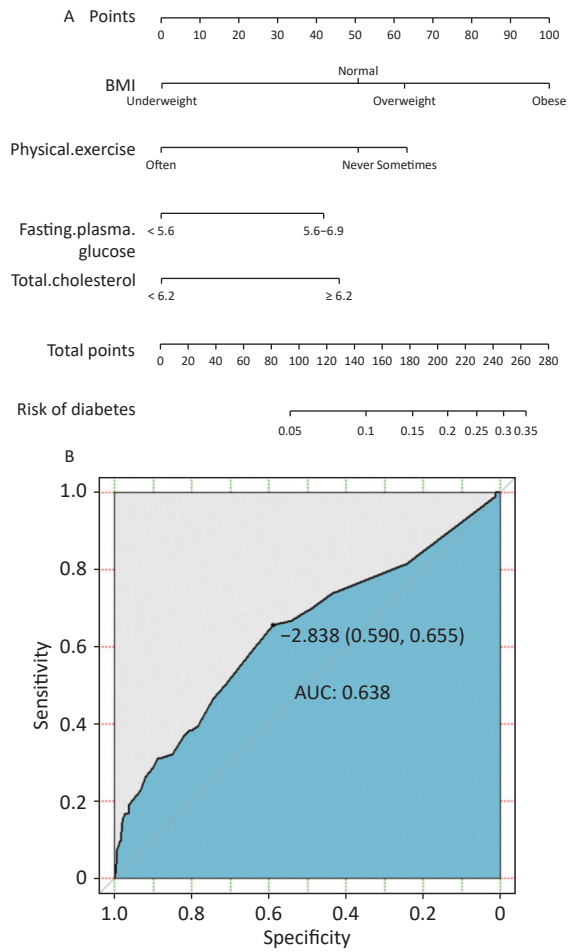
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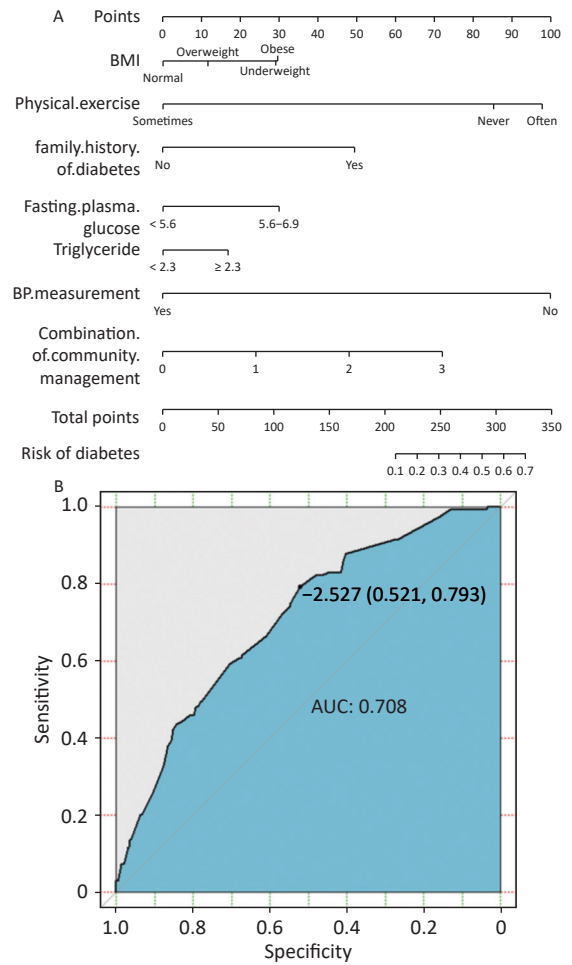
Supplementary Figure S1. Study flowchart.



Supplementary Figure S2. Nomograms (A) and ROC (B) curves for prehypertensive and hypertensive participants.



Supplementary Figure S3. Nomograms (A) and ROC (B) curves for prehypertensive participants.



Supplementary Figure S4. Nomograms (A) and ROC (B) curves for hypertensive participants.

Supplementary Table S1. Characteristics of the participants

Characteristics	Total (n = 3,151), n (%)	Prehypertension (n = 1,477), n (%)	Hypertension (n = 1,674), n (%)	P value
Sex				
Male	1,177 (37.4)	598 (40.5)	579 (34.6)	< 0.001
Female	1,974 (62.6)	879 (59.5)	1,095 (65.4)	
Age (years)	71.2 ± 6.1	71.1 ± 5.9	71.4 ± 6.2	0.086
Body mass index (BMI)				< 0.001
Underweight	61 (1.9)	36 (2.4)	25 (1.5)	0.355
Normal	1,345 (42.7)	705 (47.7)	640 (38.2)	
Overweight	1,284 (40.7)	565 (38.3)	719 (43.0)	
Obese	461 (14.6)	171 (11.6)	290 (17.3)	
Marital status				0.355
Unmarried	31 (1.0)	17 (1.2)	14 (0.8)	< 0.001
Married/Cohabitation	2,792 (88.6)	1,324 (89.6)	1,468 (87.7)	
Divorced/Separated/Widowed	328 (10.4)	136 (9.2)	45 (11.5)	
Educational level				< 0.001
Primary school or below	609 (19.3)	259 (17.5)	350 (20.9)	0.004
Junior middle school	1,057 (33.5)	459 (31.1)	598 (35.7)	
Senior middle school	795 (25.2)	413 (28.0)	382 (22.8)	
Undergraduate or above	690 (21.9)	346 (23.4)	344 (20.5)	
Annual income (¥)				0.004
< 30,000	1,537 (48.8)	664 (43.2)	873 (52.2)	0.095
30,000–50,000	1,376 (43.7)	700 (50.9)	676 (40.4)	
> 50,000	238 (7.6)	113 (7.7)	125 (7.5)	
Ethnicity				0.095
Han	3,062 (97.3)	1,429 (96.8)	1,633 (97.6)	0.002
Others	89 (2.7)	48 (3.2)	41 (2.4)	
Triglyceride (mmol/L)				0.002
< 2.3	2,642 (83.8)	1,267 (85.8)	1,073 (82.1)	0.001
≥ 2.3	509 (16.2)	210 (14.2)	601 (17.9)	
Total cholesterol (mmol/L)				0.001
< 6.2	2,724 (86.4)	1,252 (84.8)	1,472 (87.9)	0.000
≥ 6.2	427 (13.6)	225 (15.2)	202 (12.1)	
HDL-C (mmol/L)				0.000
< 4.9	507 (16.1)	170 (11.5)	337 (20.1)	< 0.001
≥ 4.9	2,644 (83.9)	1,307 (88.5)	1,337 (79.9)	
LDL-C (mmol/L)				< 0.001
< 4.1	2,623 (83.2)	1216 (82.3)	1,407 (84.1)	< 0.001
≥ 4.1	528 (16.8)	261 (17.7)	267 (15.9)	
Fasting plasma glucose (mmol/L)				< 0.001
< 5.6 (normal)	2,002 (85.8)	1,043 (89.6)	959 (82.4)	< 0.001
5.6–6.9 (IFG)	1,149 (14.2)	434 (10.4)	715 (17.6)	
Waist (cm)	85.1 ± 9.1	84.0 ± 9.0	86.3 ± 9.0	
Physical exercise				< 0.001
Never	682 (21.6)	324 (21.9)	358 (21.4)	0.244
Sometimes	164 (5.2)	60 (4.1)	104 (6.2)	
Often	2,305 (73.2)	1,093 (74.0)	1,212 (72.4)	
Current drinking	268 (8.5)	127 (8.6)	141 (8.4)	0.244
Current smoking	284 (9.0)	134 (9.1)	150 (9.0)	0.965
History of stroke	80 (2.5)	30 (2.0)	50 (3.0)	0.232
History of coronary heart disease	438 (13.9)	162 (11.0)	276 (16.5)	< 0.001
Family history of hypertension	299 (9.5)	56 (3.8)	243 (14.5)	< 0.001
Family history of stroke	80 (2.5)	9 (0.6)	19 (1.1)	0.175
Family history of diabetes	33 (1.0)	21 (1.4)	12 (0.7)	0.052
Family history of coronary heart disease	77 (2.4)	26 (1.8)	51 (3.0)	0.026

Supplementary Table S2. Univariate analysis for the risk factors associated with progression to diabetes

Characteristics	No diabetes (n = 2,927), n (%)	Diabetes (n = 224), n (%)	P value
Sex			0.503
Male	1,098 (93.9)	79 (6.7)	
Female	1,829 (92.7)	145 (7.3)	
Age (years)			0.491
60–	1,396 (93.6)	2,026 (6.4)	
70–	1,198 (92.3)	2,160 (7.7)	
80–	319 (91.9)	2,059 (8.1)	
90–	14 (93.3)	2,039 (6.7)	
BMI			< 0.001
Underweight	57 (93.4)	4 (6.6)	
Normal	1,273 (94.6)	72 (5.4)	
Overweight	1,189 (92.6)	95 (7.4)	
Obese	408 (88.5)	53 (11.5)	
Marital status			0.300
Unmarried	31 (100.0)	0 (0.0)	
Married/Cohabitation	2,592 (92.8)	200 (7.2)	
Divorced/Separated	304 (92.7)	24 (7.3)	
/Widowed			0.801
Educational level			0.971
Primary school or below	565 (92.8)	44 (7.2)	
Junior middle school	983 (93.0)	74 (7.0)	
Senior middle school	736 (92.6)	59 (7.4)	
Undergraduate or above	643 (93.2)	47 (6.8)	
Annual income (¥)			0.265
< 30,000	1,416 (92.1)	121 (7.9)	
30,000–50,000	1,288 (93.6)	88 (6.4)	
> 50,000	223 (93.7)	15 (6.3)	
Ethnicity			0.579
Han	2,843 (92.8)	219 (7.2)	
Others	84 (94.4)	5 (5.6)	
Physical exercise			0.293
Never	629 (92.2)	53 (7.8)	
Sometimes	157 (95.7)	7 (4.3)	
Often	2,141 (92.9)	164 (7.1)	
Current drinking			0.794
Yes	250 (93.3)	18 (6.7)	
No	2,677 (92.9)	206 (7.1)	
Current smoking			0.963
Yes	264 (93.0)	20 (7.0)	
No	2,663 (92.9)	204 (7.1)	

Characteristics			Continued
	No diabetes (n = 2,927), n (%)	Diabetes (n = 224), n (%)	P value
History of stroke			0.890
Yes	74 (92.5)	6 (7.5)	
No	2,853 (92.9)	218 (7.1)	
History of coronary heart disease			0.029
Yes	396 (90.4)	42 (9.6)	
No	2,531 (93.3)	182 (6.7)	
Family history of hypertension			0.594
Yes	280 (93.6)	19 (6.4)	
No	2,647 (92.8)	205 (7.2)	
Family history of stroke			0.265*
Yes	24 (85.7)	4 (14.3)	
No	2,903 (93.0)	220 (7.0)	
Family history of diabetes			0.002
Yes	26 (78.8)	7 (21.2)	
No	2,901 (93.0)	217 (7.0)	
Family history of coronary heart disease			0.003
Yes	65 (84.4)	12 (15.6)	
No	2,862 (93.1)	212 (6.9)	
Triglyceride (mmol/L)			0.026
< 2.3	2,466 (93.3)	176 (6.7)	
≥ 2.3	461 (90.6)	48 (9.4)	
Total cholesterol (mmol/L)			0.460
< 6.2	393 (92.0)	34 (8.0)	
≥ 6.2	2,534 (93.0)	190 (7.0)	
HDL-C (mmol/L)			0.446
< 4.9	475 (93.7)	32 (6.3)	
≥ 4.9	2,452 (92.7)	192 (7.3)	
LDL-C (mmol/L)			0.638
< 4.1	493 (93.4)	35 (6.6)	
≥ 4.1	2,434 (92.8)	189 (7.2)	
Fasting plasma glucose (mmol/L)			< 0.001
< 5.6 (normal)	1,902 (95.0)	100 (5.0)	
5.6–6.9 (IFG)	1,025 (89.2)	124 (10.8)	

Note. * Chi-squared test with Yates' continuity correction. IFG: impaired fasting glucose.

Supplementary Table S3. Multivariate analysis for the risk factors associated with progression to diabetes

Characteristics	<i>P</i> value	<i>RR</i>	95% <i>CI</i>
BMI			
Underweight	0.424	0.649	0.225–1.874
Normal	0.001	0.542	0.348–0.742
Overweight	0.024	0.677	0.462–0.946
Obese	0.006	1	
History of coronary heart disease			
Yes	0.113	1.344	0.933–1.937
No		1	
Family history of coronary heart disease			
Yes	0.052	1.923	0.994–3.720
No		1	
Family history of diabetes			
Yes	0.024	2.788	1.143–6.798
No		1	
Triglyceride (mmol/L)			
< 2.3		1	
≥ 2.3	0.140	1.292	0.919–1.816
Fasting plasma glucose (mmol/L)			
< 5.6 (normal)		1	
5.6–6.9 (IFG)	< 0.001	2.130	1.613–2.812

Note. 1: the reference cell. IFG: impaired fasting glucose; BMI: body mass index.

Supplementary Table S4. Univariate analysis for the risk factors associated with progression to diabetes in participants with prehypertension/hypertension

Characteristics	Prehypertension (n = 1,477)			Hypertension (n = 1,674)		
	No diabetes (n = 1,393)	Diabetes (n = 84)	P value	No diabetes (n = 1,534)	Diabetes (n = 140)	P value
Sex			0.646			0.792
Male	566 (94.6)	32 (5.4)		532 (91.9)	47 (8.1)	
Female	827 (94.1)	52 (5.9)		1,002 (91.5)	93 (8.5)	
Age (years)			0.344			0.936
60–	689 (95.3)	34 (4.7)		703 (92.1)	61 (7.9)	
70–	564 (93.5)	39 (6.5)		634 (91.2)	61 (8.8)	
80–	134 (92.4)	11 (7.6)		185 (91.6)	17 (8.4)	
90–	6 (100.0)	0 (0.0)		8 (88.9)	1 (11.1)	
BMI			0.118			0.005
Underweight	35 (97.2)	1 (2.8)		22 (88.0)	3 (12.0)	
Normal	671 (95.2)	41 (4.8)		602 (94.1)	38 (5.9)	
Overweight	532 (94.2)	37 (5.8)		657 (91.4)	62 (8.6)	
Obese	155 (90.6)	17 (9.4)		253 (87.2)	37 (12.8)	
Marital status			0.566			0.512*
Unmarried	17 (100.0)	0 (0.0)		14 (100.0)	0 (0.0)	
Married/Cohabitation	1,247 (94.2)	77 (5.8)		1,345 (91.6)	123 (8.4)	
Divorced/Separated/Widowed	129 (94.9)	7 (5.1)		175 (91.1)	17 (8.9)	
Educational level			0.730			0.877
Primary school or below	245 (94.6)	14 (5.4)		320 (91.4)	30 (8.6)	
Junior middle school	437 (95.2)	22 (4.8)		546 (91.3)	52 (8.7)	
Senior middle school	387 (93.7)	26 (6.3)		349 (91.4)	33 (8.6)	
Undergraduate or above	324 (93.6)	22 (6.4)		319 (92.7)	25 (7.3)	
Annual income (¥)			0.364			0.747
< 30,000	620 (93.4)	44 (6.6)		796 (91.2)	77 (8.8)	
30,000–50,000	666 (95.1)	34 (4.8)		622 (92.0)	54 (8.0)	
> 50,000	107 (94.7)	6 (5.3)		116 (92.8)	9 (7.2)	
Ethnicity			0.436*			0.968*
Han	1,346 (94.2)	83 (5.8)		1,497 (91.7)	136 (8.3)	
Others	47 (97.9)	1 (2.1)		37 (90.2)	4 (9.8)	
Physical exercise			0.007			0.007
Never	296 (91.4)	28 (8.6)		333 (93.0)	25 (7.0)	
Sometimes	54 (90.0)	6 (10.0)		103 (99.0)	1 (1.0)	
Often	1,043 (95.4)	50 (4.6)		1,098 (90.6)	114 (9.4)	
Current drinking			0.624			0.947
Yes	121 (95.3)	6 (4.7)		129 (91.5)	12 (8.5)	
No	1,272 (94.2)	78 (5.6)		1,405 (91.7)	128 (8.3)	
Current smoking			0.305			0.448
Yes	129 (96.3)	5 (3.7)		135 (90.0)	15 (10.0)	
No	1,264 (94.1)	79 (5.9)		1,399 (91.8)	125 (8.2)	

Continued

Characteristics	Prehypertension (n = 1,477)			Hypertension (n = 1,674)		
	No diabetes (n = 1,393)	Diabetes (n = 84)	P value	No diabetes (n = 1,534)	Diabetes (n = 140)	P value
History of stroke			0.815 [†]			0.925 [†]
Yes	28 (93.3)	2 (6.7)		46 (92.0)	4 (8.0)	
No	1,365 (94.3)	82 (5.7)		1,488 (91.6)	136 (8.4)	
History of coronary heart disease			0.083			0.242
Yes	148 (91.4)	14 (8.6)		248 (89.9)	28 (10.1)	
No	1,245 (94.7)	70 (5.3)		1,286 (92.0)	112 (8.0)	
Family history of hypertension			0.913*			0.279
Yes	53 (94.6)	3 (5.4)		227 (93.4)	16 (6.6)	
No	1,340 (94.3)	81 (5.7)		1,307 (91.3)	124 (8.7)	
Family history of stroke			0.481			0.448 [†]
Yes	8 (88.9)	1 (11.1)		16 (84.2)	3 (15.8)	
No	1,385 (94.3)	83 (5.7)		1,518 (91.7)	137 (8.3)	
Family history of diabetes			0.772 [†]			< 0.001
Yes	19 (90.5)	2 (9.5)		7 (58.3)	5 (41.7)	
No	1,374 (94.4)	82 (5.6)		1,527 (91.8)	135 (9.2)	
Family history of coronary heart disease			0.383			0.015
Yes	23 (88.5)	3 (11.5)		42 (82.4)	9 (17.6)	
No	1,370 (94.4)	81 (5.6)		1,492 (91.9)	131 (8.1)	
Triglyceride (mmol/L)			0.985			< 0.011
< 2.3	1,195 (94.3)	54 (5.7)		1,271 (92.4)	104 (7.6)	
≥ 2.3	198 (94.3)	30 (5.7)		263 (88.0)	36 (12.0)	
Total cholesterol (mmol/L)			0.024			0.433
< 6.2	1,188 (94.9)	64 (5.1)		1,346 (91.4)	108 (8.6)	
≥ 6.2	205 (91.1)	20 (8.9)		188 (93.1)	32 (6.9)	
HDL-C (mmol/L)			0.197			0.631
< 1.04	164 (96.5)	6 (3.5)		311 (92.3)	26 (7.7)	
≥ 1.04	1,229 (94.0)	78 (6.0)		1,223 (91.5)	114 (8.5)	
LDL-C (mmol/L)			0.804			0.748
< 4.1	1,146 (94.2)	56 (5.8)		1,288 (91.5)	119 (8.5)	
≥ 4.1	247 (94.6)	28 (5.4)		246 (92.1)	21 (7.9)	
Fasting plasma glucose (mmol/L)			0.002			< 0.001
< 5.6 (normal)	996 (95.0)	47 (5.0)		906 (93.3)	53 (6.7)	
5.6–6.9 (IFG)	397 (88.3)	37 (11.7)		628 (83.7)	87 (16.3)	
Antihypertensive medication						0.075
No				500 (89.9)	56 (10.1)	
Self-management				1,034 (92.5)	84 (7.5)	
Regular medication				1,156 (92.5)	94 (7.5)	0.032
Improving diet				1,162 (92.8)	90 (7.2)	0.003
Controlling salt intake				943 (93.4)	67 (6.6)	0.002
Increasing exercise				891 (92.8)	69 (7.2)	0.044
BP monitoring				909 (92.7)	72 (7.3)	0.072

Continued

Characteristics	Prehypertension (n = 1,477)			Hypertension (n = 1,674)		
	No diabetes (n = 1,393)	Diabetes (n = 84)	P value	No diabetes (n = 1,534)	Diabetes (n = 140)	P value
Combination of self- management						0.019
No				321 (88.4)	42 (11.6)	
Single management				166 (90.2)	18 (9.8)	
2 combinations				68 (88.3)	9 (11.7)	
≥ 3 combinations				979 (93.2)	71 (6.8)	
Community management						
BP measurement				1,218 (93.1)	90 (69.0)	< 0.001
Medication guidance				1,149 (92.8)	89 (7.2)	0.003
Dietary guidance				1,162 (9.8)	90 (7.2)	0.003
Physical exercise guidance				1,137 (92.7)	89 (7.3)	0.007
Combination of community-management						0.002
No				337 (87.1)	50 (12.9)	
Single management				9 (100.0)	0(0.0)	
2 combinations				32 (100.0)	0 (0.0)	
≥ 3 combinations				1,156 (92.8)	90 (7.2)	

Note. * Chi-squared test with Yates' continuity correction; Fisher's exact test. IFG: impaired fasting glucose; BMI, body mass index; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; BP, blood pressure.

Supplementary Table S5. Presence of metabolic syndrome in prehypertensive participants and hypertensive participants

Characteristics	Prehypertension (n = 1,477)			Hypertension (n = 1,674)		
	No diabetes (n = 1,393)	Diabetes (n = 84)	P value	No diabetes (n = 1,534)	Diabetes (n = 140)	P value
Waist (cm)						
≥ 90 for male or ≥ 85 for female	507 (36.4)	36 (42.9)	0.237	686 (44.7)	76 (54.3)	0.030
FPG (mmol/L)			0.000			0.000
≥ 6.1	145 (10.4)	20 (23.8)		246 (16.0)	48 (34.3)	
BP (mmHg)			0.768			
≥ 135/85	410 (29.4)	26 (31.0)		1,534 (100.0)	140 (100.0)	
TG (mmol/L)			0.111			0.001
≥ 1.7	445 (31.9)	34 (40.5)		554 (36.1)	71 (50.7)	
HDL-C (mmol/L)			0.318			0.263
<1.04	164 (11.8)	7 (8.3)		229 (14.9)	26 (18.6)	
Metabolic syndrome			0.531			0.000
Yes	151 (10.8)	11 (13.1)		468 (30.5)	72 (51.4)	

Note. FPG: fasting plasma glucose, BP: blood pressure; BP: blood pressure; TG: triglycerise; HDL-C, high-density lipoprotein cholesterol.

Supplementary Table S6. Association between the use of antihypertensive medication in hypertensive individuals at baseline and diabetes, estimated by Poisson regression

Group	Total (n = 1,674)	Diabetes (n = 140), n (%)	Adjusted RR (n = 168), n (%)	P value
Without antihypertensive medication	556	56 (10.1)	1	
With antihypertensive medication	1,118	84 (7.5)	0.704 (0.504, 0.983)	0.039

Note. 1: the reference cell. Final model adjusted for age, sex, education level, marital status, annual income, ethnicity, smoking, drinking, physical activity, BMI, stroke, coronary heart disease, family history of hypertension, family history of stroke, family history of diabetes, family history of coronary heart disease, TG, TC, HDL-C, LDL-C, and FPG.