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Trajectories of body mass index and risk of incident hypertension among a normal body mass index population: A prospective cohort study

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Abstract

It is unclear whether there are different body mass index (BMI) trajectories among a population with normal BMI levels, and the association between BMI patterns and incident hypertension is not well characterized. This prospective cohort study includes surveys conducted at baseline and three follow-ups. 3939 participants who are free of hypertension at baseline or first two follow-ups were enrolled. At baseline, the age of participants ranged from 35 to 82 years and the mean age was 45.9 years. The BMI trajectories were identified using latent mixture modeling with data from the baseline and first two follow-ups. The effects of different BMI trajectories on the development of hypertension were analyzed using a Cox proportional hazard model. Four distinct BMI trajectories were identified over the study period (2004-2010): normal-stable (n = 1456), normal-increasing (n = 2159), normal-fluctuated (n = 166), and normal-sharp-increasing (n = 158). Relative to the normal-stable BMI group, the hazard ratios (HRs) and 95% confidence intervals (CIs) after adjustment for confounding factors of the normal-increasing, normal-fluctuated, and normal-sharp-increasing groups were 1.244 (1.103-1.402), 1.331 (1.008-1.756), and 1.641 (1.257-2.142), respectively. Additionally, subgroup analysis showed that the normal-fluctuated BMI trajectory was associated with a significantly higher risk of hypertension only in women (HR = 1.362; 95% CI = 1.151-1.611). The BMI trajectories were significant predictors of hypertension incidence, and increasing BMI trajectories within the currently designated normal range were associated with an increased hypertension risk, especially in women.

Jiahui Xu and Rui Zhang contributed equally to this work.

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1 | INTRODUCTION

Hypertension, as one of the main risk factors for cardiovascular disease (CVD), is recognized as a national public health priority in China due to the heavy economic burden to the national health care system. The China PEACE Million Persons Project, which enrolled about 1.7 million community-dwelling Chinese participants aged 35-75 years, showed that 44.7% of the sample had hypertension.[1] Therefore, it is essential to identify the modifiable risk factors of hypertension to improve this situation.

Many studies have shown that a high body mass index (BMI), a commonly used indicator to reflect obesity, is associated with an increased risk of hypertension.[2-4] Although the impact of BMI on hypertension has become an increasingly important public health concern, most previous studies conducted BMI measurements at only a single point in time and ignored dynamic changes in BMI over time. In fact, BMI may change for various reasons[5,6] and the effect on outcomes may change accordingly. Especially, people with a normal BMI at baseline may be classified into the same group in typical epidemiological studies, making it impossible to estimate the potential impact of changes in BMI.

The BMI trajectory reflects the pattern of potential dynamic changes in BMI. Although the relationship between BMI and hypertension has been extensively studied, there is still a significant gap in identifying the relationship between BMI trajectory and hypertension risk during adulthood. In addition, relatively few studies have analyzed this relationship in middle-aged and elderly populations,[11] as previous studies usually focused on children, adolescents, or young adults.[7-10] To our knowledge, no study has explored the association between BMI trajectories in adulthood and the incidence of hypertension and its subtypes in a rural Chinese population.

In the present study, BMI measurements of a longitudinal cohort of a Chinese population were performed three times from 2004 to 2010 to explore the trajectory of BMI dynamics in adulthood and potential associations between BMI trajectory among participants with normal BMI and the risk of hypertension, including isolated systolic hypertension (ISH), isolated diastolic hypertension (IDH), and systolic and diastolic hypertension (SDH).

2 | METHODS

2.1 | Study population

The participants of this large-scale prospective cohort study were recruited from a rural area of Fuxin, Liaoning Province, China. Four surveys were conducted in 2004-2006, 2008, 2010, and 2017. Details of the study design and procedures are described elsewhere [12,13] (Supplementary Method S1).

A flowchart of the participant selection process is presented in Figure 1. Of 45 925 participants who agreed to participate in this study, 3883 (8.5%) were excluded because of a lack of contact information or refusal to participate in the follow-up, while 42 042 (91.5%) participants participated in at least one follow-up. Individuals who died (n = 1204), were lost to the first follow-up (n = 8332), had incomplete or extreme data regarding the main variables of BMI (n = 346) and blood pressure (BP) (n = 96) at the first follow-up, as well as those who died (n = 635), were lost to the second follow-up (n = 6347), had incomplete or extreme data regarding BMI (n = 30) or BP (n = 7) at the second follow-up, and those who died (n = 1571), were lost to the third follow-up (n = 9844), or had incomplete or extreme BP values (n = 115) at the third follow-up were also excluded. In addition, participants diagnosed with hypertension at baseline, follow-up 1, or follow-up 2 (n = 7411) were also excluded, as were those without complete data regarding confounding factors at baseline (n = 82). Due to the small sample size, those who were underweight (BMI < 18.5 kg/m^2) (n = 328) or severely obese (BMI ≥ 40 kg/m^2) (n = 37) prior to the second follow-up were further excluded.[14] Additionally, participants who were overweight at baseline (BMI ≥ 24 kg/m^2)[15] (n = 1718) were excluded. Ultimately, 3939 participants were enrolled.

The study protocol was approved by the Ethics Committee of the China Medical University (Shenyang, China) and conducted in accordance with the Ethical Principles for Medical Research Involving Human Subjects described in the Declaration of Helsinki. All participants submitted informed consent prior to study inclusion.

2.2 | Study design

The aim of this study was to explore the association between BMI trajectory subgroups and the incidence of hypertension. BMI trajectories were identified from baseline to follow-up 2. The main outcome was hypertension after follow-up 2.

2.3 | Examinations

All surveys were performed by well-trained local physicians. Demographic characteristics (age, sex, and ethnicity), lifestyle behaviors (current smoking and drinking status, physical activity),[16,17] history of disease (CVD, diabetes, hyperlipidemia), family history of hypertension, and information on the use of antihypertensive medications were collected. Assessment of relative factors is detailed in Supplementary Method S2.

Height and weight were measured using standardized procedures. BMI was calculated as weight (kg)/height $(m)^2$. Systolic BP (SBP) and diastolic BP (DBP) were measured three times using an appropriate cuff size and a standard automatic electronic sphygmomanometer in accordance with an established protocol.[18] The average of the three measurements were used for analysis. Details are given in Supplementary Method S2. During each follow-up, BP and BMI were measured and recorded using the same standard procedures as with the baseline measurements.

2.4 | Outcomes

Hypertension was defined as SBP/DBP ≥ 140/90 mmHg or use of BP-lowering medications within 2 weeks.[18] ISH was defined as SBP ≥ 140

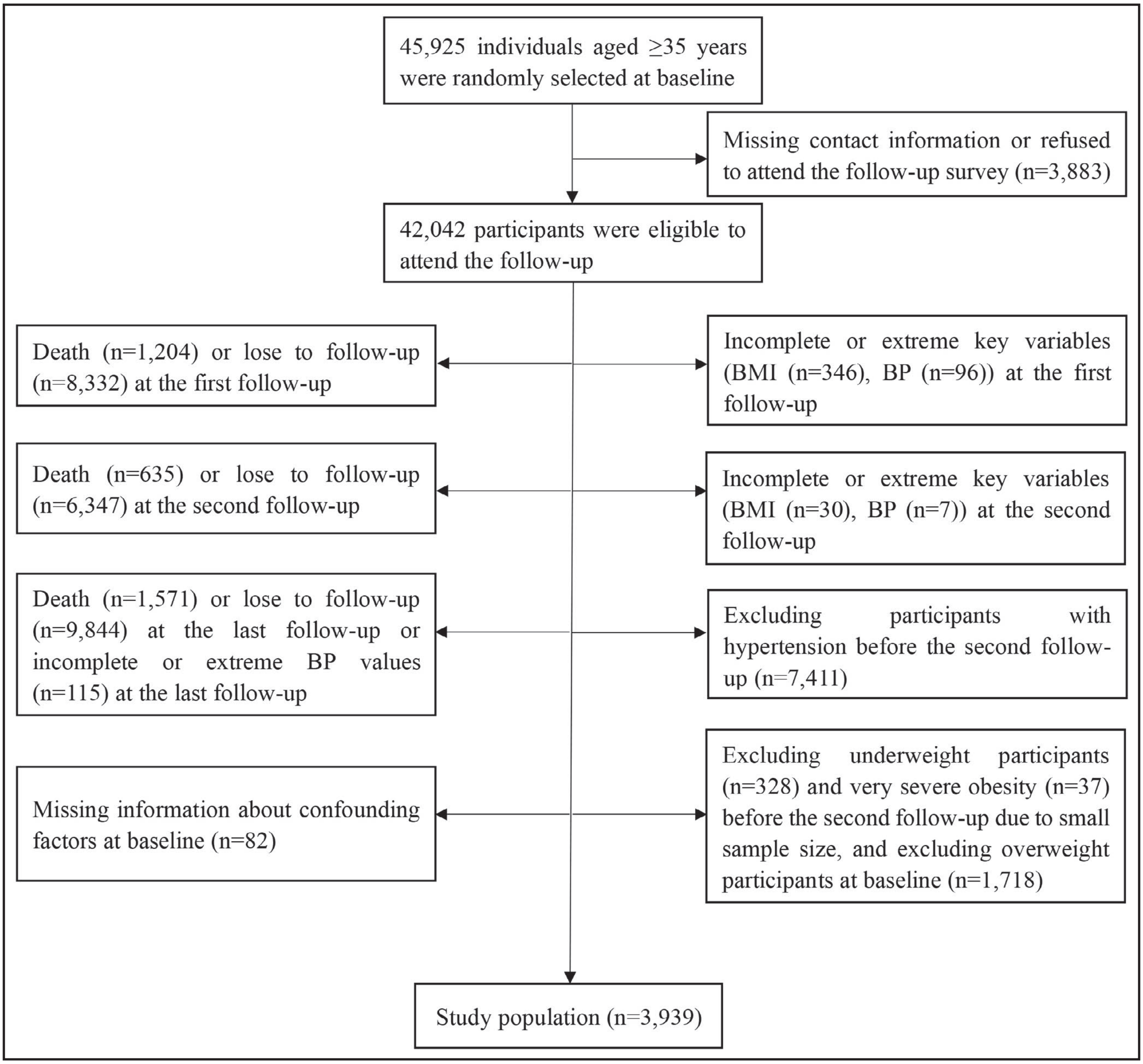

FIGURE 1 Flowchart of the participant selection process. BMI, body mass index; BP, blood pressure

and DBP < 90 mmHg, IDH as SBP < 140 and DBP ≥ 90 mmHg, and SDH as SBP ≥ 140 and DBP ≥ 90 mmHg or the use of antihypertensive medications within 2 weeks.[19] Information on antihypertensive medication use was obtained from a standard questionnaire. Information on hypertension and history of antihypertensive medication use was collected at baseline and all three follow-ups.

2.5 | Statistical analysis

Baseline characteristics are presented as the mean ± standard deviation or number (percentage). Different trajectory groups were compared using one-way analysis of variance or the χ^2 test, as appropriate. The rate of hypertension events is presented as the number of events per 1000 person-years. Latent mixture modeling (PROC TRAJ) was used to identify subgroups with a similar underlying BMI trajectory.[20] Longitudinal BMI data were fitted to a censored normal model with a polynomial function of follow-up time by changing the number of groups from 2 to 4. Then, the trajectory shapes were changed (linear and quadratic) and the analysis was repeated. The details of the polynomial with statistically significant highest order are shown in Table S1. The four trajectory groups were determined by 2, 2, 2, and 2 or three trajectory groups determined by 2, 2, and 2 or others with a nonsignificant highest order. An optimal model was created according to the following criteria: improvement in the Bayesian information criterion, membership in any single trajectory group of ≥2%, and high posterior probability of >0.7.[21] Finally, four trajectory groups determined by 1, 2, 2, and 1 were determined as the polynomial order fit best. The hazard ratios (HR) and 95% confidence intervals (CI) were calculated for the associations between exposure (BMI trajectories) and the risk of hypertension using Cox proportional hazard models, with group membership as an independent variable, adjusted for baseline age, sex, ethnicity, SBP, DBP, BMI, current drinking, current smoking, education level, physical activity, self-reported hypertension family history, and self-reported history of diabetes, hyperlipidemia, and CVD. All analyses were conducted using SPSS 22.0 (IBM SPSS Inc.) and SAS statistical software, version 9.2 (SAS Institute Inc.). A two-tailed probability (*p*) value of <.05 was considered statistically significant.

3 | RESULTS

Overall, four distinct BMI trajectories were identified from baseline to follow-up 2 among participants with a normal BMI at baseline (Figure 2). Based on the BMI range and pattern over time, the trajectory groups were, respectively, labeled as normal-stable (n = 1456, 37.0%), normal-increasing (n = 2159, 54.8%), normal-fluctuated (n = 166, 4.2%), and normal-sharp-increasing (n = 158, 4.0%) group.

The baseline characteristics of the 3939 participants stratified by the development trajectory are presented in Table 1. The age of participants (48.8% female) ranged from 35 to 82 years, and the mean age was 45.9 ± 8.5 years. The normal-fluctuated group had the highest proportion of females (65.7%) and the normal-sharp-increasing group had the highest baseline average BMI (22.5 kg/m^2), while there were significant differences in sex, ethnicity, educational level, drinking, physical activity, DBP, and BMI at baseline among the four groups.

In the normal-stable group, BMI remained at 21 kg/m^2 from baseline to follow-up 2, but slightly increased in the normal-increasing group from 22 kg/m^2 at baseline to 24 kg/m^2 at follow-up 2. In the normal-fluctuated group, BMI increased from 22 kg/m^2 at baseline to 28 kg/m^2 at follow-up 1 and then decreased to 25 kg/m^2 at follow-up 2. In the normal-sharp-increasing group, BMI increased from 22 kg/m^2 at baseline to 25 kg/m^2 at follow-up 1 and then continuously increased to 29 kg/m^2 at follow-up 2.

The incidence rates (95% CIs) of hypertension were described according to the different BMI trajectory groups (Figure 3). Over a median follow-up period of 11.24 years, there were 476, 759, 58, and 64 incidences of hypertension identified in the normal-stable, normal-increasing, normal-fluctuated, and normal-sharp-increasing groups, respectively, with corresponding incidence rates of 27.17, 29.44, 29.35, and 33.85 per 1000 person-years.

The HRs and 95% CIs for the association between the trajectory groups and incident hypertension are presented in Table 2. As compared with the reference (normal-stable) group, the HRs (95% CIs) for the normal-increasing, normal-fluctuated, and normal-sharp-increasing groups adjusted for baseline confounding factors were 1.244 (1.103-1.402), 1.331 (1.008-1.756), and 1.641 (1.257-2.142), respectively. A collinearity diagnosis based on linear regression was performed with hypertension risk as the dependent variable. As shown in Table S2, there was no significant collinearity among the independent variables (all, variance inflation factor < 10).[22]

The associations between the BMI trajectories and hypertension subtypes were also analyzed. Notably, the normal-increasing BMI pattern was associated with a higher risk of both ISH (adjusted HR = 1.269; 95% CI = 1.015-1.585) and SDH (HR = 1.275; 95% CI = 1.091-1.491) than the normal-stable BMI pattern, while the normal-fluctuated and normal-sharp-increasing BMI patterns were associated with an increased risk of SDH (HR = 1.467 and 1.938; 95% CI = 1.042-2.066 and 1.408-2.669, respectively).

The BMI trajectories according to sex and age were also explored. Three distinct BMI trajectories were identified among males: normal-stable, normal-increasing, and normal-sharp-increasing (Figure S1, Table S3). After correction for the confounding factors, as compared with the normal-stable BMI pattern, the normal-sharp-increasing BMI pattern was associated with the composite end point of hypertension incidence (HR = 1.621; 95% CI = 1.091-2.410) as well as the individual end point of SDH (HR = 2.499; 95%

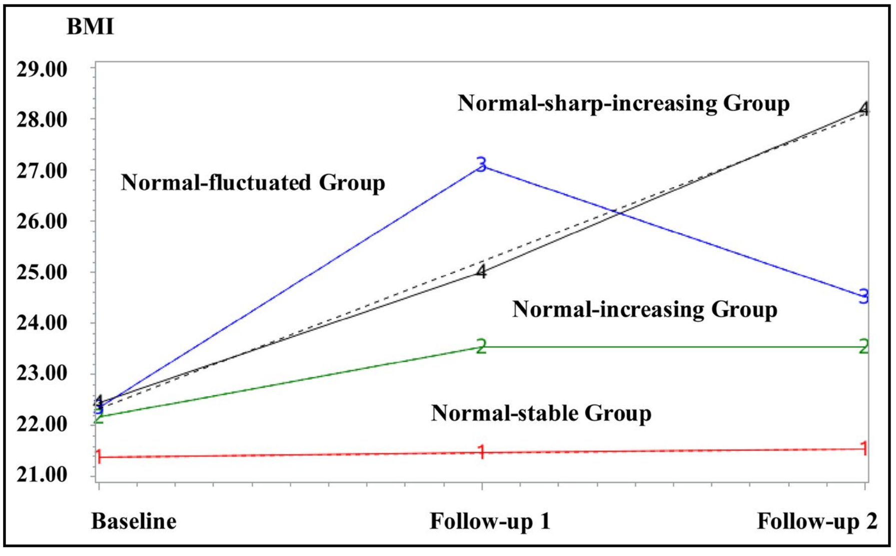

FIGURE 2 BMI trajectory patterns from 2004 to 2010. BMI, body mass index

TABLE 1 Basic characteristics at baseline according to 4 subgroups with different BMI trajectory patterns

	Total	Normal-stable	Normal-increasing	Normal-fluctuated	Normal-sharp-increasing	*p* Values
N (%)		1456 (37.0)	2159 (54.8)	166 (4.2)	158 (4.0)	
Female, *n* (%)	1922 (48.8)	727 (49.9)	996 (46.1)	109 (65.7)	90 (57.0)	<.001
Age (year)	45.9 (8.5)	46.2 (8.9)	45.6 (8.3)	46.4 (7.5)	46.6 (8.5)	.129
Ethnicity, *n* (%)						
Han nationality	3259 (82.7)	1242 (85.3)	1759 (81.5)	136 (81.9)	122 (77.2)	.029
Mongolian	624 (15.8)	198 (13.6)	364 (16.9)	29 (17.5)	33 (20.9)	
Others	56 (1.4)	16 (1.1)	36 (1.7)	1 (0.6)	3 (1.9)	
Education level, *n* (%)						
Never or less than 5 years	1415 (35.9)	613 (42.1)	709 (32.8)	52 (31.3)	41 (25.9)	<.001
Primary school	2342 (59.5)	775 (53.2)	1347 (62.4)	109 (65.7)	111 (70.3)	
Tertiary high school or higher education	182 (4.6)	68 (4.7)	103 (4.8)	5 (3.0)	6 (3.8)	
Current drinker, *n* (%)	1206 (30.6)	405 (27.8)	719 (33.3)	35 (21.1)	47 (29.7)	<.001
Current smoker, *n* (%)	1676 (42.5)	604 (41.5)	953 (44.1)	60 (36.1)	59 (37.3)	.059
Physical activity, *n* (%)						
Low	741 (18.8)	309 (21.2)	385 (17.8)	32 (19.3)	15 (9.5)	.005
Moderate	1943 (49.3)	687 (47.2)	1091 (50.5)	85 (51.2)	80 (50.6)	
High	1255 (31.9)	460 (31.6)	683 (31.6)	49 (29.5)	63 (39.9)	
History of diabetes, *n* (%)	4 (0.1)	3 (0.2)	1 (0.0)	0 (0.0)	0 (0.0)	.510
History of hyperlipidemia, *n* (%)	33 (0.8)	18 (1.2)	15 (0.7)	0 (0.0)	0 (0.0)	.167
History of CVD, *n* (%)	61 (1.5)	19 (1.3)	37 (1.7)	4 (2.4)	1 (0.6)	.492
Family history of hypertension, *n* (%)	367 (9.3)	135 (9.3)	213 (9.9)	9 (5.4)	10 (6.3)	.143
SBP (mmHg)	120.3 (10.9)	120.4 (10.8)	120.3 (11.0)	119.1 (11.4)	121.3 (10.4)	.353
DBP (mmHg)	75.2 (7.6)	74.6 (7.8)	75.4 (7.5)	75.4 (7.6)	76.0 (7.3)	.005
BMI (kg/ m^2)	21.9 (1.3)	21.3 (1.3)	22.2 (1.2)	22.3 (1.3)	22.5 (1.2)	<.001

Note: Values are expressed as mean (standard deviation) or number (percentage).

Abbreviations: BMI, body mass index; CVD, cardiovascular disease; DBP, diastolic blood pressure; SBP, systolic blood pressure.

CI = 1.629-3.836). However, there was no significant association between the normal-increasing BMI pattern and hypertension risk.

Three distinct BMI trajectories were identified among females: normal-stable, normal-fluctuated, and normal-sharp-increasing (Figure S2, Table S4). As compared with the normal-stable BMI pattern, both the normal-fluctuated and normal-sharp-increasing BMI patterns were associated with a relatively higher risk of hypertension (HR = 1.362 and 1.593; 95% CI = 1.151-1.611 and 1.151-2.203, respectively).

Besides, by definition, in an aging society, the elderly population aged ≥65 years accounts for more than 7% of the total population. Therefore, the study participants were divided into two groups based on age (<65 vs. ≥65 years). However, due to the limited number of those aged ≥65, the BMI trajectory was only fitted with participants aged <65 years. A similar trend was found among those aged <65 years. There were four different trajectory groups (Figure S3, Table S5). Both the normal-increasing and normal-sharp-increasing BMI patterns were significantly associated with an increased risk of hypertension (HR = 1.231 and 1.629; 95% CI = 1.089-1.391 and 1.245-2.132, respectively).

4 | DISCUSSION

In this study, different trajectories of adult BMI were identified by latent mixture modeling. This differs from traditional research methods in which participants are divided into several subgroups based on various characteristics, while usually ignoring population heterogeneity, which may result in failure to accurately identify internal relationships.[23-25] There can be exceptionally large individual differences in BMI levels and dynamic changes over time, thus dynamic trajectories of BMI may more accurately predict the risk of hypertension.

Overall, four different trajectories were observed among adults with normal BMI levels in rural China in this large prospective cohort study with a 11.24-year follow-up period. Notably, the

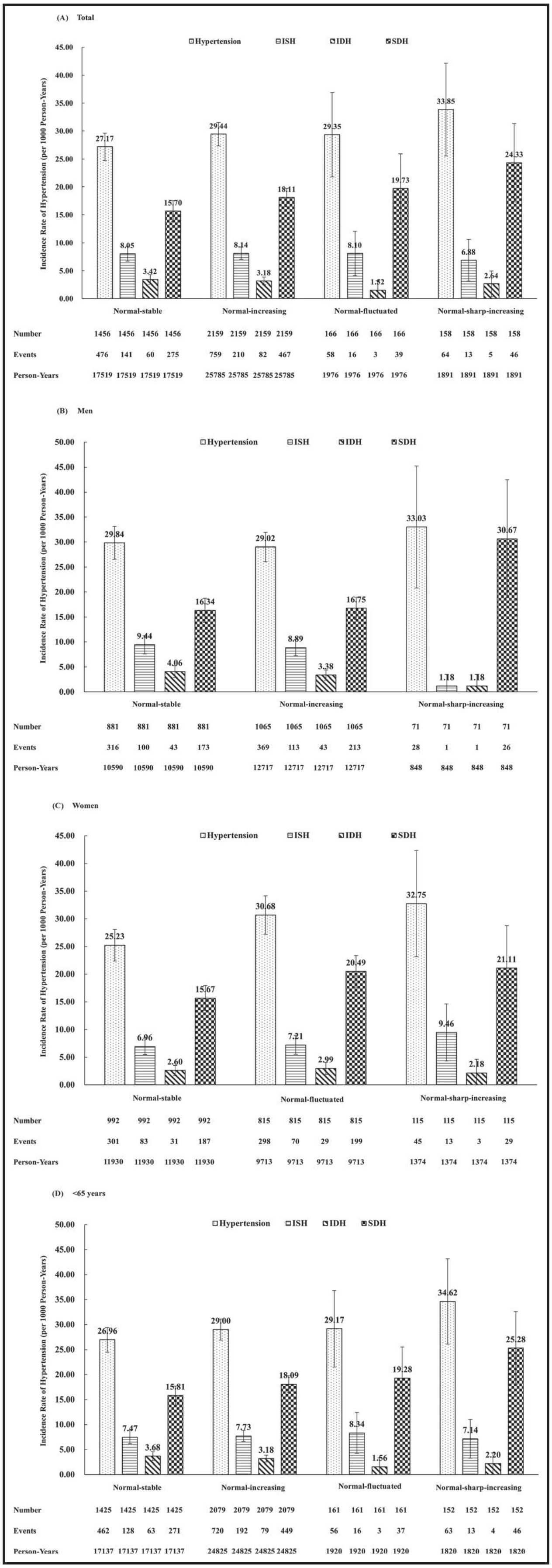

FIGURE 3 The incidence rates (95%CIs) of hypertension by different BMI trajectories. IDH, isolated diastolic hypertension; ISH, isolated systolic hypertension; SDH, systolic and diastolic hypertension

normal-increasing, normal-fluctuated, and normal-sharp-increasing BMI patterns were associated with significantly higher risks for hypertension as compared to the normal-stable BMI pattern. Even though individuals in the normal-increasing trajectory subgroup had BMI values that remained in the normal range (18.5-24 kg/m^2), they were still at a significantly higher risk of hypertension as compared to those in the normal-stable trajectory group, in which the BMI remained consistent at 21 kg/m^2.

Previous studies have described associations between BMI trajectories and the risk of hypertension.[7-11] For example, the Isle of Wight birth cohort study showed that the BMI trajectory significantly differed during the first 18 years of life, which was associated with a higher risk of elevated BP.[7] Moreover, a survey of 3271 participants indicated that BMI trajectory has a significant impact on the risk of hypertension in young adulthood and that the age of 20-30 years is a critical period for the development of hypertension.[8] The association between BMI trajectories and adverse outcomes has been explored in studies conducted in the European Union and the United States. For example, Buscot et al[9] identified six discrete BMI trajectories and found that persisting high BMI levels were associated with CVD risk factors among Finnish adults. The results of the present study also showed that a normal-increasing trajectory was associated with a significantly higher risk of hypertension possibly due to the cumulative effect of increased visceral adiposity, influence of inflammation, and activation of the sympathetic nervous system and the renin-angiotensin-aldosterone system.[2,26-28] In addition, even within the normal range, an increase in BMI can still promote the occurrence of hypertension, which was not mentioned in previous studies, but can be supported by two possible explanations. First, even if the BMI has not yet reached the overweight level, the damage caused by an increase in BMI still has a cumulative effect, thereby increasing the risk of hypertension. Second, there may be differences in population characteristics, as in the present study, which explored the relationship between BMI trajectories and the onset of hypertension in a Chinese rural population aged >35 years. Besides, other researchers have observed that participants who were previously overweight but currently of normal weight were not at a higher risk of hypertension than individuals who maintained normal weight.[29,30] Inconsistently, the results of the present study illustrate that the normal-fluctuated trajectory can also affect the incidence of hypertension, especially in women. Meanwhile, a previous randomized trial showed that despite successful weight loss, only 72% of patients achieved a decrease in BP.[31] Therefore, the risk of BMI gain cannot completely be completely offset by a reduction in BMI possibly because of BMI-induced change in sympathetic tone, which acts through adaptation as seen with the baroreceptor response, could lead to increased tone that does not respond to a decrease in BMI.[32]

TABLE 2 HRs and 95% CIs of BMI trajectory groups for incident hypertension[a]

	Hypertension		ISH		IDH		SDH	
	HR (95%CI)	p Value	HR (95%CI)	p Value	HR (95%CI)	p Value	HR (95%CI)	p Value
Total								
Normal-stable	1.000 (ref.)		1.000 (ref.)		1.000 (ref.)		1.000 (ref.)	
Normal-increasing	1.244 (1.103, 1.402)	<.001	1.269 (1.015, 1.585)	.036	1.078 (0.759, 1.529)	.676	1.275 (1.091, 1.491)	.002
Normal-fluctuated	1.331 (1.008, 1.756)	.044	1.408 (0.832, 2.381)	.202	0.524 (0.162, 1.687)	.278	1.467 (1.042, 2.066)	.028
Normal-sharp-increasing	1.641 (1.257, 2.142)	<.001	1.212 (0.681, 2.158)	.513	1.141 (0.449, 2.899)	.781	1.938 (1.408, 2.669)	<.001
Men								
Normal-stable	1.000 (ref.)		1.000 (ref.)		1.000 (ref.)		1.000 (ref.)	
Normal-increasing	1.146 (0.977, 1.344)	.094	1.261 (0.945, 1.683)	.115	0.984 (0.627, 1.544)	.945	1.151 (0.930, 1.424)	.196
Normal-sharp-increasing	1.621 (1.091, 2.410)	.017	0.213 (0.030, 1.539)	.125	0.461 (0.062, 3.423)	.449	2.499 (1.629, 3.836)	<.001
Women								
Normal-stable	1.000 (ref.)		1.000 (ref.)		1.000 (ref.)		1.000 (ref.)	
Normal-fluctuated	1.362 (1.151, 1.611)	<.001	1.169 (0.837, 1.633)	.36	1.295 (0.764, 2.196)	.337	1.436 (1.163, 1.772)	.001
Normal-sharp-increasing	1.593 (1.151, 2.203)	.005	1.715 (0.934, 3.149)	.082	1.104 (0.327, 3.725)	.873	1.608 (1.071, 2.413)	.022
<65 years								
Normal-stable	1.000 (ref.)		1.000 (ref.)		1.000 (ref.)		1.000 (ref.)	
Normal-increasing	1.231 (1.089, 1.391)	.001	1.263 (1.000, 1.595)	.05	1.010 (0.712, 1.431)	.957	1.269 (1.084, 1.486)	.003
Normal-fluctuated	1.268 (0.957, 1.681)	.099	1.386 (0.818, 2.348)	.225	0.501 (0.156, 1.613)	.247	1.369 (0.965, 1.943)	.078
Normal-sharp-increasing	1.629 (1.245, 2.132)	<.001	1.257 (0.704, 2.245)	.439	0.890 (0.318, 2.493)	.825	1.928 (1.399, 2.656)	<.001

Abbreviations: BMI, body mass index; DBP, diastolic blood pressure; IDH, isolated diastolic hypertension; ISH, isolated systolic hypertension; SBP, systolic blood pressure; SDH, systolic and diastolic hypertension.

[a]Adjusted for baseline age, sex, ethnicity, SBP, DBP, BMI, education level, physical activity, current drinking, current smoking, diabetes history, hyperlipidemia history, hypertension family history and cardiovascular disease history.

Besides, Julio et al[33] found that ISH and SDH account for most cases of obesity-related hypertension among US adult men, while a study by Visaria and Lob[34] of 790 641 adults aged ≥20 years showed that BMI was more strongly associated with IDH than other hypertension subtypes in non-obese American and Indian adults. The results of the present study indicate that participants with a normal-increasing BMI pattern were at a higher risk of ISH and SDH, but not IDH, while the normal-fluctuated and normal-sharp-increasing BMI patterns were associated with an increased risk of only SDH. As a possible explanation for this result is that an increase in SBP is mainly related to arteriosclerosis, while an increase is DBP is caused by increased peripheral resistance.[35,36] Furthermore, an increase in BMI is associated with heightened BP via enhanced vascular volume or peripheral resistance.[32]

Although the potential mechanisms were not sufficiently clarified, these findings provide some evidence that the optimal status of BMI may be a normal-stable pattern. As a major risk factor of CVD, hypertension results in great physical discomfort to the patient and substantial economic burdens to the patients and their families. Thus, it is particularly important to propose early interventions for risk factors to prevent hypertension.

There were several strengths to this study. First, latent mixture modeling was used to identify different BMI trajectories, which effectively reduces possible misclassifications. Second, the sample size was relatively large and the median follow-up period was exceptionally long at 11.24 years. Third, the study participants were recruited from the general population with good representation. Hence, this prospective cohort study provides stronger evidence than cross-sectional studies and studies based on specific populations for effective prevention of hypertension based on the dynamic trajectory of risk factors.

There were also several limitations to this study that should be considered. First, the study cohort was limited to a Chinese rural population, which may limit generalizability of the results. Hence, further studies are needed among representative populations with different demographic characteristics. Second, there were insufficient laboratory measurements (eg, serum glucose and cholesterol), which may be potential confounding factors. Third, participants with hypertension before follow-up 2 were excluded, and thus the association of BMI trajectory was assessed from the baseline to the first two follow-ups with the risk of hypertension at follow-up 3. Of an original population of 42 042, only 3939 participants were included for analysis after exclusion due to death, loss to follow-up, and incomplete data, which may lead to the low representativeness of the study.

5 | CONCLUSIONS

In conclusion, heterogeneity in BMI levels exists in the Chinese population. Different BMI trajectories were positively associated with incident hypertension. Normal-increasing, normal-fluctuated, and normal-sharp-increasing BMI trajectories were strongly correlated to the risk of hypertension. Therefore, exposure to various risk factors may play an essential role in the occurrence and development of hypertension and CVD. Hence, the identification of different trajectories in a population may provide evidence for early prevention.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

AUTHOR CONTRIBUTIONS

Liqiang Zheng contributed to conceptualization; Jiahui Xu contributed to methodology; Rui Zhang, Yanxia Xie and Jia Zheng involved in formal analysis; Rongrong Guo, Yali Wang, Yue Dai and Liying Xing involved in investigation; Jiahui Xu contributed to writing—original draft; Liqiang Zheng and Yingxian Sun contributed to writing—review and editing; Yingxian Sun involved in supervision; Zhaoqing Sun involved in project administration.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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