Blood Pressure Trajectory and Its Influencing Factors in Chinese Adults: A Cohort Study with Long-Term Follow-Up

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Background: Few studies have been reported on the factors affecting the trajectory of blood pressure in Chinese adults. This study aimed to identify the pattern of blood pressure trajectories and analyze the factors affecting different trajectories.

Material/Methods: A total of 749 participants were included in this study from the China Health and Nutrition Survey (CHNS) database, collected between 1989 and 2006, and were followed up until 2015. A group-based trajectory model was used to identify similar development trajectories of blood pressure levels. Univariate and multivariate logistic regression analysis was used to explore the influencing factors of blood pressure trajectories.

Results: Three systolic (SBP) and diastolic blood pressure (DBP) trajectory groups were identified: Group 1, “low initial blood pressure and slight rise” (SBP, n=267, 35.65%); Group 2, “low initial blood pressure and moderate rise” (SBP, n=375, 50.07%); and Group 3, “high initial blood pressure and high rise” (SBP, n=107, 14.29%). In the SBP trajectory groups, age $\geq 40$ years, male sex, body mass index (BMI) $\geq 24$ kg/m$^2$, and the eastern region of China were associated with a rapid rise and high baseline blood pressure ($P<0.01$). In terms of DBP trajectory, male sex, BMI $\geq 24$ kg/m$^2$, and the eastern region of China were also related to the rapid rise and high baseline blood pressure, while age may not affect rise rate ($P<0.01$).

Conclusions: Different blood pressure trajectories and related influencing factors may provide information for targeted interventions, especially for people with high initial blood pressure and high rise.

Keywords: Blood Pressure • Database • Risk Factors

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Background

High blood pressure is associated with the prevalence and mortality of vascular diseases [1]. In 2017, there were an estimated 10.4 million deaths worldwide associated with higher systolic blood pressure (SBP, 110-115 mmHg) [2]. A large nationally representative survey showed that 23.2% of Chinese adults have hypertension [3]. The impact of blood pressure on an individual's health is a matter of concern in China. Previous studies on the relationship between blood pressure and vascular diseases were mainly based on single or a small amount of blood pressure measurements [4,5]. Long-term blood pressure monitoring is a better indicator of an individual's health than is a single measurement [6]. Long-term changes in an individual's blood pressure over time can provide information for disease prevention and treatment.

Blood pressure trajectory can reflect long-term changes in an individual's blood pressure. Several studies have assessed the association between blood pressure trajectory and cardiovascular diseases [7-9]. However, these studies were limited to short-term changes in blood pressure, such as in childhood, adulthood, and middle age. There was little evidence of blood pressure trajectory patterns over a longer period. In addition, studies on blood pressure trajectories have been more focused on SBP [7,10], while there are few studies on DBP. Hao et al indicated that there were differences in the relationship of SBP and DBP with disease [8]. Furthermore, current studies have been mostly about the relationship between blood pressure trajectory and disease, and there are few studies on the factors affecting different blood pressure trajectory patterns.

In this study, we aimed to identify the pattern of the blood pressure trajectory in Chinese adults based on the China Health and Nutrition Survey (CHNS) database with long-term follow-up data and to analyze the factors that may affect the blood pressure trajectories.

Material and Methods

Study Design and Population

This was a retrospective cohort study. All data were extracted from the CHNS database, which is an ongoing large-scale household survey that has been conducted since 1989 and was followed up every 2 to 4 years until 2015 [11]. We extracted data between 1989 and 2006. A multistage, random cluster sampling process was used to draw the samples surveyed in 9 provinces (east: Shandong and Jiangsu; central: Henan, Hubei, and Hunan; west: Guanzhi and Guizhou; northeast: Heilongjiang and Liaoning). The exclusion criteria were as follows: (1) age <18 years old; (2) diagnosed with hypertension at baseline; (3) without complete blood pressure data; and (4) lost follow-up. In addition, to extrapolate the results to the general population, 5 participants with diabetes were excluded. All included participants had complete follow-up data collected for 10 consecutive times. The survey protocols, instruments, and process for obtaining informed consent for CHNS were approved by the Ethics Committee of the National Institute of Nutrition and Food Safety of the Chinese Center for Disease Control and Prevention and the Institutional Review Board of the University of North Carolina at Chapel Hill [12].

Blood Pressure Measurement

In each measurement, the participants remained seated after resting for at least 5 min. All trained health workers or nurses followed the standardized procedure using a calibrated mercury sphygmomanometer and measured the blood pressure of the participant’s right arm. Blood pressure was measured 3 times at 30-s intervals, and the mean of the 3 measurements was used as the measured value. SBP was measured when the pulse sound first appeared (Korotkoff phase 1), and DBP was measured when the pulse sound disappeared (Korotkoff phase 5) [13].

Other Variables

Demographic data of participants were collected and included age (<30, 30-39, and ≥40 years), sex (male or female), body mass index (BMI <24 kg/m², not overweight/obesity; BMI ≥24 kg/m², overweight/obesity), waist-hip ratio (WHR, normal, WHR <0.9 in men or WHR<0.85 in women; central obesity, WHR ≥0.9 in men or WHR ≥0.85 in women), education level (illiteracy, primary school, middle school, and high school or above), history of smoking (yes or no), alcohol consumption (yes or no), diabetes mellitus (yes or no), region (east, center, and west), and type of residence (rural or urban).

Trajectory Grouping

A group-based trajectory model was used to identify similar development trajectories of blood pressure levels [14]. We modeled the blood pressure trajectories of all recruited participants. First, a base model without covariate was constructed to determine the number of groups and the order of the polynomial functions of the survey wave. The best-fit model was considered to be the trajectory group with the highest probability and was based on the goodness of fit statistic using the Bayesian information criterion (BIC) (the one with the absolute value of BIC closest to zero was selected as the appropriate model). The BIC results indicated that the model with 3 groups with up to cubic order terms fitted the best (Supplementary Figure 1). Second, each participant was assigned to the corresponding trajectory group according to the
Participants enrolled in CHNS (n=1003)

- Excluded (n=254)
  - Age <18 years old (n=17)
  - Missing blood pressure data (n=21)
  - Last follow-up (n=211)
  - Have diabetes (n=5)

Participants enrolled in CHNS (n=1003)

- Systolic blood pressure (SBP) trajectory groups:
  - Low initial BP and slight rise (Group 1, n=267)
  - Low initial BP and moderate rise (Group 2, n=375)
  - High initial BP and high rise (Group 3, n=107)

- Diastolic blood pressure (DBP) trajectory groups:
  - Low initial BP and slight rise (Group 1, n=305)
  - High initial BP and slight rise (Group 2, n=366)
  - High initial BP and high rise (Group 3, n=78)

maximum likelihood estimation to estimate the probability of variance generated blood pressure of each group.

**Statistical Analysis**

Measures of central tendency such as mean ± standard deviation was used to analyze the data with a normal distribution, and the t test was used for comparison between groups. Data with a non-normal distribution or outliers was described by median and interquartile range (M [Q1, Q3]), and comparison between groups was performed using the Mann-Whitney U rank-sum test. Enumeration data were described in terms of number and proportion (n [%]), and comparison between groups was performed by the χ² test or Fisher’s exact probability method. Univariate analysis was performed on the baseline variables, and variables with statistical significance were included in multivariate logistic regression analysis to explore the influencing factors of blood pressure trajectory.

All statistical analyses were done using a 2-sided test, and P<0.05 was considered statistically significant. All analyses were done with SAS9.4 software (SAS Institute Inc, Cary, NC, USA).

**Results**

**Characteristics of Participants**

A total of 749 participants were included in this study (Figure 1). Of these participants, 275 (36.72%) were men, 474 (63.28%) were women. The age distribution of individuals aged <30, 30-39, and ≥40 years old was 25.10% (188 participants), and 49.53% (371 participants), and 25.37% (190 participants), respectively. There were 653 (87.18%) participants with overweight/obesity, and 96 (12.82%) participants without overweight/obesity. From a regional perspective, there were 298 (39.79%) participants in eastern China, 328 (43.79%) participants in central China, and 123 (16.42%) participants in western China (Table 1).

**Characteristics of the Blood Pressure Trajectory Groups**

To characterize each group’s blood pressure trajectory, the initial blood pressure values (initial BP), the last follow-up blood pressure values (end BP), and the average annual percent change (AAPC) of each trajectory were added.

Three separate trajectories in SBP were identified (Figure 2A) and called “low initial BP and slight rise”, “low initial BP and moderate rise”, and “high initial BP and high rise”. The low initial BP and slight rise group (Group 1; initial BP, 103.25±10.64 mmHg; end BP, 118.52±11.39 mmHg; AAPC, 0.5% [95% CI, 0.4-0.7]; n=267, 35.65%) was characterized by maintaining a relatively low SBP level and slowly increasing. The low initial BP and moderate rise group (Group 2; initial BP, 111.47±11.42 mmHg; end BP, 137.62±15.24 mmHg; AAPC, 0.8% [95% CI, 0.7-0.9]; n=375, 50.07%) was characterized by a relatively low SBP level and faster increase than Group 1. The high initial BP and high rise group (Group 3; initial BP, 121.14±14.17 mmHg; end BP, 154.51±17.15 mmHg; AAPC, 1.1% [95% CI, 0.9-1.2]; n=107, 14.29%) was characterized by a relatively high and rapid increase in BP level. Consistent with the SBP trajectories, 3 isolated trajectory groups were identified in DBP (Figure 2B). The numbers and proportions of participants in the low initial BP and slight rise (Group 1; initial BP, 65.49±7.95 mmHg; end BP, 74.98±7.77 mmHg; AAPC, 0.4% [95% CI, 0.3-0.6]), high initial BP and slight rise [Group 2; initial BP, 73.07±8.50 mmHg; end BP, 80.10±7.44 mmHg; AAPC, 0.4% [95% CI, 0.3-0.5]), and high
initial BP and high rise (Group 3; initial BP, 75.98±9.34 mmHg; end BP, 90.82±10.13 mmHg; AAPC, 0.8% [95% CI, 0.6-0.9])
groups were 305 (40.72%), 366 (48.87%), and 78 (10.41%), respectively. The detailed characteristics of each SBP and DBP trajectory group are displayed in Table 2.

Comparison of Characteristics Between Different Blood Pressure Trajectory Groups

The results showed that there were statistical differences between different SBP and DBP trajectory groups in age (SBP: $\chi^2=42.131$, $P<0.001$; DBP: $\chi^2=10.289$, $P=0.036$), regional distribution (SBP: $\chi^2=37.698$, $P<0.001$; DBP: $\chi^2=37.088$, $P<0.001$), sex (SBP: $\chi^2=18.860$, $P<0.001$; DBP: $\chi^2=23.420$, $P<0.001$), BMI (SBP: $\chi^2=17.637$, $P<0.001$; DBP: $\chi^2=19.025$, $P<0.001$), and alcohol consumption (SBP: $\chi^2=6.250$, $P=0.044$; DBP: $\chi^2=9.689$, $P=0.008$). Detailed analyses are shown in Tables 3 and 4.

SBP and DBP Trajectories in Different Participants

The trajectories of SBP and DBP among different participants are shown in Figure 3. In the age subgroup, participants aged ≥40 years and 30-39 years had higher SBP levels than did participants aged <30 years ($P<0.05$), while no statistical differences were observed in DBP levels ($P>0.05$; Figure 3A). Men had higher SBP and DBP levels than women, but there were no statistically significant differences ($P>0.05$; Figure 3B). In terms of BMI, participants with BMI ≥24 kg/m² had higher SBP and DBP levels than did those with BMI <24 kg/m², but no significant difference was observed ($P>0.05$; Figure 3C). In terms of regional distribution, participants located in the eastern region had the highest SBP and DBP levels, and the only significant difference in DBP levels was between the eastern region and western region ($P<0.05$); no other comparisons were significant ($P>0.05$; Figure 3D).

### Table 1. Characteristics of all included participants.

| Variables                        | Total (n=749) |
|----------------------------------|--------------|
| Age (years), n (%)               |              |
| <30                              | 188 (25.10)  |
| 30-39                            | 371 (49.53)  |
| ≥40                              | 190 (25.37)  |
| Gender, n (%)                    |              |
| Male                             | 275 (36.72)  |
| Female                           | 474 (63.28)  |
| BMI (kg/m²), n (%)               |              |
| Non-overweight-obesity (≤24.0)   | 653 (87.18)  |
| Overweight-obesity (≥24.0)       | 96 (12.82)   |
| Waist-hip ratio, n (%)           |              |
| Normal (male <0.9, female <0.85) | 591 (78.91)  |
| Central obesity (male ≥0.9, female ≥0.85) | 158 (21.09) |
| Education level, n (%)           |              |
| Illiteracy                       | 304 (40.59)  |
| Primary school                   | 198 (26.44)  |
| Middle school                    | 175 (23.36)  |
| High school or above             | 72 (9.61)    |
| Smoking, n (%)                   |              |
| No                               | 544 (72.63)  |
| Yes                              | 205 (27.37)  |

| Variables                        | Total (n=749) |
|----------------------------------|--------------|
| Alcohol consumption, n (%)       |              |
| No                               | 546 (72.90)  |
| Yes                              | 203 (27.10)  |
| Region, n (%)                    |              |
| East                             | 298 (39.79)  |
| Center                           | 328 (43.79)  |
| West                             | 123 (16.42)  |
| Type of residence, n (%)         |              |
| Rural                            | 149 (19.89)  |
| Urban                            | 600 (80.11)  |
| SBP trajectory groups, n (%)     |              |
| SBP-Group 1                      | 267 (35.65)  |
| SBP-Group 2                      | 375 (50.07)  |
| SBP-Group 3                      | 107 (14.29)  |
| DBP trajectory groups, n (%)     |              |
| DBP-Group 1                      | 305 (40.72)  |
| DBP-Group 2                      | 366 (48.87)  |
| DBP-Group 3                      | 78 (10.41)   |

BMI – body mass index; SBP – systolic blood pressure; DBP – diastolic blood pressure; SBP-Group 1 – low initial BP and slight rise; SBP-Group 2 – low initial BP and moderate rise; SBP-Group 3 – high initial BP and high rise; DBP-Group 1 – low initial BP and slight rise; DBP-Group 2 – high initial BP and slight rise; DBP-Group 3 – high initial BP and high rise.
The factors associated with the DBP trajectory groups are shown in Figure 4. In the comparison between Group 2 and Group 1 (Model 1), Group 2 had more men [odds ratio (OR)=2.17; 95% confidence interval (CI), 1.55-3.06], BMI $\geq 24$ kg/m$^2$ (OR=1.84; 95% CI, 1.09-3.11), while Group 1 had more participants located in the central region (OR=0.53; 95% CI, 0.38-0.76) and western region (OR=0.28; 95% CI, 0.17-0.44). In the comparison between Group 3 and Group 1 (Model 2), participants aged $\geq 40$ years (OR=3.27; 95% CI, 1.50-7.13), male sex (OR=2.90; 95% CI, 1.66-5.07), and BMI $\geq 24$ kg/m$^2$ (OR=4.59; 95% CI, 2.28-9.25) were associated with the Group 3 DBP trajectory and participants located in central region (OR=0.56; 95% CI, 0.31-0.99) and western region (OR=0.24; 95% CI, 0.10-0.58) were associated with the DBP trajectory in Group 1.

The factors related to the SBP trajectory are shown in Figure 5. The Group 2 SBP trajectory was associated with aged $\geq 40$ years (OR=2.26; 95% CI, 1.39-3.69), male sex (OR=2.12; 95% CI, 1.49-3.02), and BMI $\geq 24$ kg/m$^2$ (OR=2.22; 95% CI, 1.26-3.92), while the Group 1 SBP trajectory was associated with central region (OR=0.64; 95% CI, 0.44-0.92) and western region (OR=0.29; 95% CI, 0.18-0.47). Similar to the Group 2 SBP trajectory, the
In this study, the blood pressure trajectory of Chinese adults and its influencing factors were analyzed based on the long-term follow-up data of the CHNS database. Our results indicated that the SBP and DBP trajectories of Chinese adults can be divided into 3 groups. In the SBP trajectory, age ≥40 years, male sex, BMI ≥24 kg/m², and eastern regions may be factors that affected the rapid rise and high baseline blood pressure. In terms of DBP trajectory, male sex, BMI ≥24 kg/m², and eastern region were also associated with the rapid rise and high baseline blood pressure, while age may not affect the rise of DBP trajectory.

High blood pressure is an important factor for certain diseases, such as cardiovascular diseases [15]. A single blood pressure measurement may not be sufficient to characterize long-term disease prediction, and blood pressure trajectory is a good indicator of long-term changes [16,17]. Three blood pressure trajectories of Chinese adults were shown in this study. The blood pressure trajectories of Group 1 and Group 2 reflected the blood pressure trajectories of normal people with different rates of increase, while Group 3 reflected the blood pressure trajectories of patients who may have hypertension. Different blood pressure trajectories were associated with different risks of the same disease [10,16]. Shen et al indicated that adult hypertension can originate in childhood, and the long-term blood pressure levels of patients with hypertension were higher than that of the normal population [18]. Understanding the differences in blood pressure between individuals over time can provide information for tailored prevention and treatment strategies.

We compared the differences between different blood pressure trajectory groups to find factors that may affect blood pressure trajectory. Our results showed that male sex, BMI ≥24 kg/m², and eastern regions were related to the rapid rise and high baseline blood pressure of the SBP and DBP trajectories. In addition, age ≥40 years may affect the SBP trajectory but not the DBP trajectory. The study of Cheng et al indicated that older age, male sex, and high BMI were positively associated with an increase in all blood pressure measures [19]. The influence of sex on blood pressure is controversial.

Table 2. Characteristics of each systolic blood pressure and diastolic blood pressure trajectory group.

| Groups | 1989 | 1991 | 1993 | 1997 | 2000 | 2004 | 2006 | 2009 | 2011 | 2015 | AAPC (%) |
|--------|------|------|------|------|------|------|------|------|------|------|---------|
| SBP    |      |      |      |      |      |      |      |      |      |      |         |
| Group 1| 103.25 ±10.64 | 101.87 ±9.79 | 103.40 ±10.70 | 105.54 ±10.37 | 105.1 ±10.31 | 106.91 ±10.89 | 108.66 ±10.93 | 113.14 ±11.32 | 112.53 ±11.22 | 114.5 ±11.39 | 0.5 (0.4-0.7) |
| Group 2| 114.47 ±11.42 | 110.34 ±11.10 | 112.98 ±11.19 | 116.23 ±11.84 | 117.77 ±11.79 | 121.13 ±11.41 | 123.75 ±12.64 | 129.86 ±13.50 | 130.29 ±14.43 | 137.62 ±15.24 | 0.8 (0.7-0.9) |
| Group 3| 121.14 ±14.17 | 120.02 ±14.24 | 122.37 ±15.62 | 133.24 ±18.67 | 135.80 ±19.75 | 140.32 ±18.37 | 143.41 ±18.67 | 150.64 ±19.70 | 151.88 ±17.96 | 154.51 ±17.15 | 1.1 (0.9-1.2) |
| DBP    |      |      |      |      |      |      |      |      |      |      |         |
| Group 1| 65.49 ±7.95 | 65.04 ±8.10 | 67.53 ±8.42 | 68.35 ±7.79 | 67.35 ±7.70 | 68.01 ±7.75 | 69.50 ±7.49 | 71.60 ±7.41 | 69.60 ±7.18 | 74.98 ±7.77 | 0.4 (0.3-0.6) |
| Group 2| 73.07 ±8.50 | 71.95 ±8.53 | 74.07 ±8.41 | 74.44 ±7.93 | 76.79 ±8.23 | 76.18 ±8.13 | 77.14 ±7.90 | 79.25 ±7.06 | 77.95 ±6.85 | 80.10 ±7.44 | 0.4 (0.3-0.5) |
| Group 3| 75.98 ±9.34 | 75.09 ±9.78 | 77.84 ±9.04 | 82.22 ±10.36 | 82.67 ±10.47 | 86.02 ±11.08 | 85.08 ±10.38 | 90.98 ±10.52 | 89.32 ±9.54 | 90.82 ±10.13 | 0.8 (0.6-0.9) |

Group 3 SBP trajectory was associated with age 30-39 years (OR=2.85; 95% CI, 1.36-5.98) and ≥40 years (OR=11.08; 95% CI, 4.99-24.58), male sex (OR=2.31; 95% CI, 1.33-4.02), and BMI ≥24 kg/m² (OR=4.66; 95% CI, 2.17-9.98), and the Group 1 SBP trajectory was associated with participants living in the central region (OR=0.48; 95% CI, 0.28-0.83) and western region (OR=0.10; 95% CI, 0.04-0.26).

Discussion

In this study, the blood pressure trajectory of Chinese adults and its influencing factors were analyzed based on the long-term follow-up data of the CHNS database. Our results indicated that the SBP and DBP trajectories of Chinese adults can be divided into 3 groups. In the SBP trajectory, age ≥40 years, male sex, BMI ≥24 kg/m², and eastern regions may be factors that affected the rapid rise and high baseline blood pressure. In terms of DBP trajectory, male sex, BMI ≥24 kg/m², and eastern region were also associated with the rapid rise and high baseline blood pressure, while age may not affect the rise of DBP trajectory.

High blood pressure is an important factor for certain diseases, such as cardiovascular diseases [15]. A single blood pressure measurement may not be sufficient to characterize long-term disease prediction, and blood pressure trajectory is a good indicator of long-term changes [16,17]. Three blood pressure trajectories of Chinese adults were shown in this study. The blood pressure trajectories of Group 1 and Group 2 reflected the blood pressure trajectories of normal people with different rates of increase, while Group 3 reflected the blood pressure trajectories of patients who may have hypertension. Different blood pressure trajectories were associated with different risks of the same disease [10,16]. Shen et al indicated that adult hypertension can originate in childhood, and the long-term blood pressure levels of patients with hypertension were higher than that of the normal population [18]. Understanding the differences in blood pressure between individuals over time can provide information for tailored prevention and treatment strategies.
Table 3. Comparison of systolic blood pressure trajectory groups.

| Variables                        | Total (n=749) | Group 1 (n=267) | Group 2 (n=375) | Group 3 (n=107) | Statistic   | P       |
|----------------------------------|---------------|-----------------|-----------------|-----------------|-------------|---------|
| Age (years), n (%)               |               |                 |                 |                 | $\chi^2=42.131$ | $<0.001$|
| <30                              | 188 (25.10)   | 87 (32.58)      | 89 (23.73)      | 12 (11.21)      |             |         |
| 30-39                            | 371 (49.53)   | 134 (50.19)     | 192 (51.20)     | 45 (42.06)      |             |         |
| ≥40                              | 190 (25.37)   | 46 (17.23)      | 94 (25.07)      | 50 (46.73)      |             |         |
| Gender, n (%)                    |               |                 |                 |                 | $\chi^2=18.860$ | $<0.001$|
| Male                             | 275 (36.72)   | 71 (26.59)      | 162 (43.20)     | 42 (39.25)      |             |         |
| Female                           | 474 (63.28)   | 196 (73.41)     | 213 (56.80)     | 65 (60.75)      |             |         |
| BMI (kg/m$^2$), n (%)            |               |                 |                 |                 | $\chi^2=17.637$ | $<0.001$|
| Non-overweight-obesity (<24.0)   | 653 (87.18)   | 247 (92.51)     | 324 (86.40)     | 82 (76.64)      |             |         |
| Overweight-obesity (≥24.0)       | 96 (12.82)    | 20 (7.49)       | 51 (13.60)      | 25 (23.36)      |             |         |
| Waist-hip ratio, n (%)           |               |                 |                 |                 | $\chi^2=0.669$ | 0.716   |
| Normal (male <0.9, female <0.85) | 591 (78.91)   | 215 (80.52)     | 293 (78.13)     | 83 (77.57)      |             |         |
| Central obesity (male ≥0.9, female ≥0.85) | 158 (21.09) | 52 (19.48) | 82 (21.87) | 24 (22.43) |             |         |
| Education level, n (%)           |               |                 |                 |                 | $\chi^2=4.954$ | 0.550   |
| Illiteracy                       | 304 (40.59)   | 111 (41.57)     | 148 (39.47)     | 45 (42.06)      |             |         |
| Primary school                   | 198 (26.44)   | 59 (22.10)      | 108 (28.80)     | 31 (28.97)      |             |         |
| Middle school                    | 175 (23.36)   | 70 (26.22)      | 83 (22.13)      | 22 (20.56)      |             |         |
| High school or above             | 72 (9.61)     | 27 (10.11)      | 36 (9.60)       | 9 (8.41)        |             |         |
| Smoking, n (%)                   |               |                 |                 |                 | $\chi^2=0.712$ | 0.701   |
| No                               | 544 (72.63)   | 189 (70.79)     | 276 (73.60)     | 79 (73.83)      |             |         |
| Yes                              | 205 (27.37)   | 78 (29.21)      | 99 (26.40)      | 28 (26.17)      |             |         |
| Alcohol consumption, n (%)       |               |                 |                 |                 | $\chi^2=6.250$ | 0.044   |
| No                               | 546 (72.90)   | 208 (77.90)     | 267 (71.20)     | 71 (66.36)      |             |         |
| Yes                              | 203 (27.10)   | 59 (22.10)      | 108 (28.80)     | 36 (33.64)      |             |         |
| Region, n (%)                    |               |                 |                 |                 | $\chi^2=37.698$ | $<0.001$|
| East                             | 298 (39.79)   | 77 (28.84)      | 167 (44.53)     | 54 (50.47)      |             |         |
| Center                           | 328 (43.79)   | 121 (45.32)     | 161 (42.93)     | 46 (42.99)      |             |         |
| West                             | 123 (16.42)   | 69 (25.84)      | 47 (12.53)      | 7 (6.54)        |             |         |
| Type of residence, n (%)         |               |                 |                 |                 | $\chi^2=2.356$ | 0.308   |
| Rural                            | 149 (19.89)   | 49 (18.35)      | 73 (19.47)      | 27 (25.23)      |             |         |
| Urban                            | 600 (80.11)   | 218 (81.65)     | 302 (80.53)     | 80 (74.77)      |             |         |

BMI – body mass index; Group 1 – low initial BP and slight rise; Group 2 – low initial BP and moderate rise; Group 3 – high initial BP and high rise.
## Table 4. Comparison of diastolic blood pressure trajectory groups.

| Variables                                | Total (n=749) | Group 1 (n=305) | Group 2 (n=366) | Group 3 (n=78) | Statistic  | P      |
|-------------------------------------------|---------------|-----------------|-----------------|---------------|------------|--------|
| Age (years), n (%)                        |               |                 |                 |               | χ²=10.289  | 0.036  |
| <30                                       | 188 (25.10)   | 80 (26.23)      | 95 (25.96)      | 13 (16.67)    |            |        |
| 30-39                                     | 371 (49.53)   | 159 (52.13)     | 177 (48.36)     | 35 (44.87)    |            |        |
| ≥40                                       | 190 (25.37)   | 66 (21.64)      | 94 (25.68)      | 30 (38.46)    |            |        |
| Gender, n (%)                             |               |                 |                 |               | χ²=23.420  | <0.001 |
| Male                                      | 275 (36.72)   | 81 (26.56)      | 157 (42.90)     | 37 (47.44)    |            |        |
| Female                                    | 474 (63.28)   | 224 (73.44)     | 209 (57.10)     | 41 (52.56)    |            |        |
| BMI (kg/m²), n (%)                        |               |                 |                 |               | χ²=19.025  | <0.001 |
| Non-overweight-obesity (<24.0)            | 653 (87.18)   | 279 (91.48)     | 317 (86.61)     | 57 (73.08)    |            |        |
| Overweight-obesity (≥24.0)                | 96 (12.82)    | 26 (8.52)       | 49 (13.39)      | 21 (26.92)    |            |        |
| Waist-hip ratio, n (%)                    |               |                 |                 |               | χ²=1.189   | 0.552  |
| Normal (male <0.9, female <0.85)          | 591 (78.91)   | 246 (80.66)     | 286 (78.14)     | 59 (75.64)    |            |        |
| Central obesity (male ≥0.9, female ≥0.85) | 158 (21.09)   | 59 (19.34)      | 80 (21.86)      | 19 (24.36)    |            |        |
| Education level, n (%)                    |               |                 |                 |               | χ²=8.447   | 0.207  |
| Illiteracy                                | 304 (40.59)   | 129 (42.30)     | 146 (39.89)     | 29 (37.18)    |            |        |
| Primary school                            | 198 (26.44)   | 70 (22.95)      | 109 (29.78)     | 19 (24.36)    |            |        |
| Middle school                             | 175 (23.36)   | 78 (25.57)      | 73 (19.95)      | 24 (30.77)    |            |        |
| High school or above                      | 72 (9.61)     | 28 (9.18)       | 38 (10.38)      | 6 (7.69)      |            |        |
| Smoking, n (%)                            |               |                 |                 |               | χ²=1.436   | 0.488  |
| No                                        | 544 (72.63)   | 215 (70.49)     | 273 (74.59)     | 56 (71.79)    |            |        |
| Yes                                       | 205 (27.37)   | 90 (29.51)      | 93 (25.41)      | 22 (28.21)    |            |        |
| Alcohol consumption, n (%)                |               |                 |                 |               | χ²=9.689   | 0.008  |
| No                                        | 546 (72.90)   | 239 (78.36)     | 258 (70.49)     | 49 (62.82)    |            |        |
| Yes                                       | 203 (27.10)   | 66 (21.64)      | 108 (29.51)     | 29 (37.18)    |            |        |
| Region, n (%)                             |               |                 |                 |               | χ²=37.088  | <0.001 |
| East                                      | 298 (39.79)   | 87 (28.52)      | 174 (47.54)     | 37 (47.44)    |            |        |
| Center                                    | 328 (43.79)   | 144 (47.21)     | 151 (41.26)     | 33 (42.31)    |            |        |
| West                                      | 123 (16.42)   | 74 (24.26)      | 41 (11.20)      | 8 (10.26)     |            |        |
| Type of residence, n (%)                  |               |                 |                 |               | χ²=5.141   | 0.076  |
| Rural                                     | 149 (19.89)   | 59 (19.34)      | 67 (18.31)      | 23 (29.49)    |            |        |
| Urban                                     | 600 (80.11)   | 246 (80.66)     | 299 (81.69)     | 55 (70.51)    |            |        |

Group 1 – low initial BP and slight rise; Group 2 – high initial BP and slight rise; Group 3 – high initial BP and high rise.
Influencing factors of blood pressure trajectory

DATABASE ANALYSIS

B

Male
Female

SBP

100
110
120
130
140

Year
1989 1991 1993 1997 2000 2004 2006 2009 2011 2015

Male
Female

DBP

65
70
75
80
85

Year
1989 1991 1993 1997 2000 2004 2006 2009 2011 2015

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their BMI. Our results also found that participants located in eastern regions had a higher risk of high blood pressure trajectory than those located in central and western regions. The newest China Hypertension Survey indicated that participants in the southeast had the highest hypertension prevalence [23], which may support our results. Among these factors that affected blood pressure trajectory, BMI deserves significant attention because it is controllable.

Several studies have suggested that blood pressure trajectories are the important predictors of some disease morbidity and mortality as well as all-cause mortality among patients with different blood pressure levels [7,17]. Portegies et al discovered that rapidly increasing blood pressure trajectories are associated with a high risk of stroke and death [10]. Allen et al found that a higher blood pressure trajectory in youth is related to an increased risk of coronary artery calcification in middle age [24]. The study of Zheng et al found that participants with higher and increasing blood pressure trajectories...
### DBP logistic regression forestplot

| Variables | Model 1 |   |   | Model 2 |   |   |
|-----------|---------|---|---|---------|---|---|
|           | OR (95% CI) | P value | OR (95% CI) | P value |
| Age       |         |         |         |         |
| <30       | 0.94 (0.64-1.38) | 0.759 | 1.34 (0.64-2.78) | 0.415 |
| 30-39     | 1.20 (0.76-1.89) | 0.435 | 3.27 (1.50-7.13) | 0.003 |
| ≥40       | Ref      |       | Ref      |       |
| Gender    |         |         |         |         |
| Female    | 2.17 (1.55-3.06) | <0.001 | 2.90 (1.66-5.07) | <0.001 |
| Male      | Ref      |       | Ref      |       |
| BMI (kg/m²) |         |         |         |         |
| <24       | 1.04 (1.09-3.11) | 0.023 | 4.59 (2.28-9.25) | <0.001 |
| ≥24       | Ref      |       | Ref      |       |
| Region    |         |         |         |         |
| East      | 0.53 (0.38-0.76) | <0.001 | 0.56 (0.31-0.99) | 0.048 |
| Center    | Ref      |       | Ref      |       |
| West      | 0.28 (0.17-0.44) | <0.001 | 0.24 (0.10-0.58) | 0.001 |

Note: Model 1 represents a comparison between Group 1 and Group 2, with Group 1 as the reference. Model 2 represents a comparison between Group 1 and Group 3, with Group 1 as the reference.

**Figure 4.** Logistic regression forest plot of the factors associated with the diastolic blood pressure trajectory groups.

### SBP logistic regression forestplot

| Variables | Model 1 |   |   | Model 2 |   |   |
|-----------|---------|---|---|---------|---|---|
|           | OR (95% CI) | P value | OR (95% CI) | P value |
| Age       |         |         |         |         |
| <30       | 1.46 (0.99-2.14) | 0.055 | 2.85 (1.36-5.98) | 0.006 |
| 30-39     | 2.26 (1.39-3.69) | 0.001 | 11.08 (4.99-24.58) | <0.001 |
| ≥40       | Ref      |       | Ref      |       |
| Gender    |         |         |         |         |
| Female    | 2.12 (1.49-3.02) | <0.001 | 2.31 (1.33-4.02) | 0.003 |
| Male      | Ref      |       | Ref      |       |
| BMI (kg/m²) |         |         |         |         |
| <24       | 2.22 (1.26-3.92) | 0.006 | 4.66 (2.17-9.98) | <0.001 |
| ≥24       | Ref      |       | Ref      |       |
| Region    |         |         |         |         |
| East      | 0.64 (0.44-0.92) | 0.017 | 0.48 (0.28-0.83) | 0.008 |
| Center    | Ref      |       | Ref      |       |
| West      | 0.29 (0.18-0.47) | <0.001 | 0.10 (0.04-0.26) | <0.001 |

Note: Model 1 represents a comparison between Group 1 and Group 2, with Group 1 as the reference. Model 2 represents a comparison between Group 1 and Group 3, with Group 1 as the reference.

**Figure 5.** Logistic regression forest plot of the factors related to the systolic blood pressure trajectory groups.
are more likely to develop subclinical renal disease in middle age [25]. Through the analysis of individual blood pressure trajectories, it may be possible to find the risk of some diseases earlier, and timely prevention and treatment are of great significance to disease control.

Our study divided the blood pressure trajectory of Chinese adults into 3 groups based on more than 20 years of follow-up data and analyzed the factors that affected the blood pressure trajectories. However, our study had some limitations. First, our sample size was not large compared with that of other studies. Also, owing to the long follow-up period, there were fewer eligible participants. Second, some factors, such as dietary patterns, have an important influence on blood pressure trajectories [26], but these factors were not included in this study.

Conclusions

Our study identified 3 SBP and DBP trajectories in Chinese adults and analyzed the influencing factors of blood pressure trajectory. Factors such as male sex, BMI ≥24 kg/m², and eastern region were associated with the rapid increase and high baseline blood pressure of SBP and DBP trajectories, while age may not affect the rise of DBP trajectory. This study may provide information for the prevention and treatment of blood pressure-related diseases.

Declaration of Figures’ Authenticity

All figures submitted have been created by the authors, who confirm that the images are original with no duplication and have not been previously published in whole or in part.

Supplementary Figure 1. Bayesian Information Criterion (BIC) and trajectory types.

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