Influencing factors of wide pulse pressure in an elderly Chinese population: A cross-sectional study

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Abstract
Blood pressure and pulse pressure (PP) had their own characteristics in the elderly population. This cross-sectional study including 5030 elderly participants was conducted to describe the distribution of blood pressure and wide PP in the elderly population and find influencing factors of wide PP. Wide PP was defined as PP equal to or more than 65 mmHg, and was classified three types as low systolic blood pressure (SBP) and low diastolic blood pressure (DBP) (LSLD), high SBP and low DBP (HSLD), and high SBP and high DBP (HSHD). Using multivariate logistic regression models to analyze the associations of demographic factors, health-related factors and lifestyle factors with different wide PP types. The associations of lifestyles with wide PP by gender were estimated by subgroup analyses. Among 5030 elderly participants, 2727 (54.2%) participants had wide PP. Logistic regression models showed older age (OR = 2.48, 95%CI: 2.14-2.88), female (OR = 1.31, 95%CI: 1.07-1.60), not married (OR = 1.26, 95%CI: 1.07-1.49), having chronic diseases (OR = 1.28, 95%CI: 1.09-1.50), current alcohol drinker (OR = 1.29, 95%CI: 1.11-1.50) were positively associated, and higher body height (OR = .78, 95%CI: .62-.99), higher education level (OR = .60, 95%CI: .43-.82), current smoker (OR = .79, 95%CI: .64-.97) were negatively associated with wide PP. Among three different types of wide PP including LSLD, HSLD, HSHD, these factors had different effects. Subgroup analyses found that only among male, current smoker was negatively associated and current alcohol drinker was positively associated with wide PP.

KEYWORDS
blood pressure, elderly, influencing factor, wide pulse pressure
1 | INTRODUCTION

The burden of hypertension is increasing rapidly worldwide due to the global aging, and the prevalence of hypertension in adults is predicted to increase by 60% to a total of 1.56 billion (1.54 billion-1.58 billion) in 2025 according to the diagnostic criteria (systolic blood pressure [SBP] ≥ 140 mmHg, or diastolic blood pressure [DBP] ≥ 90 mmHg), which is used in most countries. However, the American College of Cardiology (ACC) and American Heart Association (AHA) changed the blood pressure threshold value and recommended new goals of SBP/DBP < 130/80 mmHg in 2017 hypertension guideline. More adults will be diagnosed as hypertensive patients by the newest American guideline, especially in the elderly population. Studies have pointed out that blood pressure varied in the elderly with increasing age, performed as SBP continuing to rise, DBP declining, and PP being widened finally.

Pulse pressure (PP) is another index of blood pressure which is defined as the difference between SBP and DBP, representing the maximal and minimal pressures fluctuation during a cardiac cycle. The normal PP is about 40 mmHg, and more than 60 mmHg is clinically considered as wide PP. Wide PP is related to some chronic diseases such as chronic kidney disease, diabetes and stroke as well as some neurological diseases like cognitive decline and dementia. Moreover, wide PP is an independent predictor of extensive cardiovascular disease. Taking an individual’s SBP and DBP into consideration, wide PP patients can divide into three types of low SBP and low DBP (LSLD), high SBP and low DBP (HSLD), and high SBP and high DBP (HSHD). The antihypertensive treatment has focused on SBP only for a long time. However, PP can better reflect cardiovascular status in the elderly population due to the blood pressure characteristics of changing with increasing age.

Hypertension is always related to some unhealthy state or behaviors, such as overweight and obesity, a high-salt diet, smoking, excessive alcohol consumption, inadequate physical activity, sleep disorders. These factors cause physiological and psychological changes in the human body and lead to hypertension finally. But evidence that how these risk factors influence the individual’s SBP or DBP was not consistent. And studies about the influencing factors about different types of wide PP were limited.

Therefore, we aimed to describe the distribution of blood pressure in the elderly Chinese population and found influencing factors of wide PP in this study.

2 | METHODS

2.1 | Study design and participants

The study participants were derived from the baseline population of Yiwu Elderly Cohort Study from 2019 to 2021. This cohort were conducted in Yiwu, Zhejiang province of China. The participants were chosen as following inclusion criteria: (1) age was and above 65 years and (2) living in the study area at least 5 years. Individuals were excluded if they were bed-ridden, had hearing disorders, serious physiological or psychological illnesses. From baseline population, a total of 5090 elderly residents responded to the questionnaire and among them, 5033 residents participated in the physical examination. For this cross-sectional study, 5033 individuals who both completed the physical examination and the questionnaire were included. Three persons who lacked information on blood pressure were excluded. Finally, 5030 eligible objects were included in further analysis in the study.

2.2 | Measurement of wide PP

For the participants, left and right brachial artery of SBP and DBP were measured after sitting quietly for 5 min by a professional medical staff. The final SBP and DBP were calculated as mean of left and right arms. PP was calculated as SBP minus DBP. Taking the approximate median value PP = 65 mmHg as cut-off value, all the elderly were divided into the normal PP (PP < 65 mmHg) group and the wide PP group (PP ≥ 65 mmHg) And in the wide PP group, according to the approximate median cut-off values SBP = 140 mmHg and DBP = 75 mmHg, participants were divided into three wide PP groups: LSDL (SBP < 140 and DBP < 75 mmHg), HSLD (SBP ≥ 140 and DBP < 75 mmHg), and HSHD (SBP ≥ 140 and DBP ≥ 75 mmHg).

2.3 | Measurement of potential influencing factors

Face-to-face interviewer-administered questionnaires were used to assess demographic factors (age, gender, body height, marital status, and educational level), health-related factors (number of chronic diseases and body mass index [BMI]), and lifestyle factors (smoking, alcohol drinking, tea drinking, and sleep quality).

BMI was calculated as weight (kilograms)/height $^2$(meters) and classified as underweight, normal weight, overweight and obesity according to the index <18.5, ≥18.5 and <24.0, ≥24.0 and <28.0, and ≥28.0. The number of chronic diseases was counted by self-reported history of chronic diseases, including hypertension, diabetes, stroke, coronary heart disease, osteoarthritis, chronic obstructive pulmonary disease and Parkinson's disease arthritis. It was categorized into three groups including no chronic disease, one kind of disease, and two or more kinds of diseases.

The smoking, alcohol drinking and tea drinking were categorized as current, former and never status. More than one cigarette per day for at least 3 months was defined as current smoker; Once smoked but gave up for 6 months was defined as former smoker. More than 100 g alcohol per week for at least 3 months was defined as current alcohol drinker; Once alcohol drank but gave up for 6 months was defined as former alcohol drinker. At least 2 times per week for more than 2 months was defined as current tea drinker; Once tea drank but gave up for 6 months was defined as former tea drinker.

The scale was divided into 7 components as sleep quality, time to fall asleep, time to sleep, sleep efficiency, sleep disorders, sleep drug use and daytime dysfunction, with each component being 0–3 points. The
total score of the scale was 21. The sleep quality was classified as very good, fairly good, fairly bad and very bad according to PSQI in 0 to 5, 6–10, 11–15 and 16–21.22

2.4 | Statistical analysis

Characteristics of participants were described using means ± standard deviation (SD) for continuous variables with normal distribution, median (interquartile range, IQR) for non-normally distributed variables, and frequency (proportion) for categorical variables. Differences between participants in the normal group and the wide PP group were tested using t-test and non-parametric Wilcoxon test for continuous variables and Chi-square tests for categorical variables. Differences between participants in the normal group and LSLD, HSLD, and HSHD groups were tested using analysis of variance (ANOVA) and Kruskal-Wallis H test for continuous variables, and Chi-square tests for categorical variables, and Dunnett’s test and partitions of Chi-square method were used for post hoc tests. Taking the normal group as reference, multivariate logistic regression models were used to analyze the odds ratios (ORs) and 95% confidence intervals (95% CIs) of demographic factors, health-related factors and lifestyle factors in total, and different types of wide PP groups respectively. Considering the great difference about the four lifestyles of smoking, alcohol drinking, tea drinking, and sleep quality between males and females, subgroup analyses were performed to assess the associations of lifestyles with wide PP by gender. A value of $p<.05$ was considered statistically significant. All statistical analyses were performed in R software (version4.1.1).

3 | RESULTS

A total of 5030 participants ≥65 years old were included in this cross-sectional study finally, including 2460 males (48.9%). The IQR of age was from 67 to 76 years old, with the median value of 71 years. The average body height was 160 cm. According to BMI category, 56.5% participants were normal while 37.0% were overweight and obesity, and the median value (IQR) of BMI was 22.96 (21.03, 25.02) kg/m². 79.5% of the participants were married and 70.2% had a primary education. The proportions of current smokers, current drinkers and current tea drinkers were not high, accounting for 13.7%, 27.5%, and 11.7%, respectively. 66.1% of the elderly had very good sleep while 4.4% had fairly bad sleep. 25.6% of participants reported they have not been diagnosed chronic diseases, 38.9% had one and 35.4% had more than two diseases. The basic characteristics of the participants were shown in Table 1.

Descriptive results showed that the median value (IQR) of SBP, DBP, PP in the elderly of Yiwu were 141(130, 154) mmHg, 75(68, 82) mmHg and 66(57, 77) mmHg. According to the grouping of the approximate median cut-off value of PP, 2303(45.8%) persons were in the normal group and 2727(54.2%) persons were in the wide PP group. Then according to the approximate median cut-off value of SBP = 140 mmHg and DBP = 75 mmHg, participants in the wide PP group were categorized as three types, including 482(17.7%) in LSLD, 877(32.1%) in HSLD, and 1368(50.2%) in HSHD. Compared to the normal group, the ages of participants in all three different types of wide PP were older, the body heights were smaller, and the proportions of the males, the married, and the non-chronic disease were lower. BMI were relatively smaller in LSLD and larger in HSHD. The results were presented in Table 1.

Figure 1 showed the samples, proportions, ORs (95% CIs) for demographic factors (age, gender, body height, marital status, educational level), health-related factors (number of chronic diseases, BMI) and lifestyle factors (smoking, alcohol drinking, tea drinking, sleep quality) between the normal group and the wide PP group. Taking the normal group as reference, the results showed that older age (OR = 2.48, 95% CI: 2.14-2.88), female (OR = 1.31, 95% CI: 1.07-1.60), the not married (OR = 1.26, 95% CI: 1.07-1.49), having single (OR = 1.36, 95% CI: 1.17-1.59) or multiple (OR = 1.28, 95% CI: 1.09-1.50) chronic diseases and current alcohol drinker (OR = 1.29, 95% CI: 1.11-1.50) were positively associated with wide PP, whereas larger body height (OR = .78, 95% CI: .62-.99), higher education level (OR = .60, 95% CI: .43-.82), current smoker (OR = .79, 95% CI: .64-.97) were negatively associated with wide PP in elderly. BMI, tea drinking and sleep quality were not statistically associated with wide PP.

ORs (95% CIs) for these factors in LSLD, HSLD, HSHD groups were presented in Figure 2. Positive associations were found between age and all three groups, and the OR value was biggest in HSLD group. Positive associations were also found between female and LSLD, HSLD groups, widowed and others and HSHD group. Larger body height was negatively associated with HSLD group, and higher education level was negatively associated with HSLD, HSHD two groups. Compared to the normal BMI, the ORs (95% CIs) of overweight were .74(.57, .95) in LSLD group, .91(.74, 1.11) in HSLD group, and 1.27(1.08, 1.50) in HSHD group. In HSLD group, having single (OR = 1.46, 95% CI: 1.16-1.84) or multiple (OR = 1.54, 95% CI: 1.22-1.95) chronic diseases both showed positive associations. In HSHD group, only having single chronic disease (OR = 1.36, 95% CI: 1.13-1.64) showed positive association. Current smoker (OR = .66, 95% CI: .51-.85) was negatively associated while current alcohol drinker (OR = 1.48, 95% CI: 1.24-1.76) was negatively associated with HSHD group. Tea drinking and sleep quality were no statistical significance between all the groups.

Subgroup analyses conducted by gender for lifestyle factors and all types of wide PP were presented in Table 2. Among male, current smoker still had a negative association while current alcohol drinker was positive in the wide PP group. Tea drinking and sleep quality had no statistical significance in wide PP group. Among female, smoking, alcohol drinking and tea drinking were not statistically significant with wide PP. Compared to having very good sleep, fairly bad sleep quality had a critical positive association with wide PP.

4 | DISCUSSION

This study described the distribution of blood pressure, especially PP in the elderly population and examined the associations between...
|                             | Overall (N = 5030) | Normal group\(^a\) (N = 2303) | Wide PP group\(^b\) | LSLD\(^c\) (N = 482) | HSLD\(^d\) (N = 877) | HSHD\(^e\) (N = 1368) | p-Value\(^f\) |
|-----------------------------|-------------------|---------------------------------|---------------------|----------------------|----------------------|----------------------|----------------|
| **Median (IQR)**            |                   |                                 |                     |                      |                      |                      |                 |
| Age (years)                 | 71.0 (67.0, 76.0) | 69.0 (66.5, 73.0)               | 72.0 (68.0, 78.0)   | 72.0 (69.0, 77.0)   | 74.0 (69.0, 80.0)   | 72.0 (68.0, 77.0)   | <.001          |
| Body height (cm)            | 160.0 (154.0, 166.0) | 161.0 (155.0, 167.5)       | 158.5 (153.0, 165.0) | 158.0 (153.0, 164.5) | 157.0 (152.0, 163.0) | 159.0 (153.0, 165.6) | <.001          |
| BMI (kg/m²)                 | 22.96 (21.03, 25.02) | 22.94 (21.05, 25.10)       | 22.96 (20.98, 24.94) | 22.49 (20.46, 24.29) | 22.81 (20.66, 24.80) | 23.34 (21.30, 25.31) | <.001          |
| Frequency (n, %)            |                   |                                 |                     |                      |                      |                      |                 |
| Male                        | 2460 (48.9%)      | 1276 (55.4%)                  | 1184 (43.4%)        | 211 (43.8%)          | 346 (39.5%)          | 627 (45.8%)          | <.001          |
| Married                     | 3998 (79.5%)      | 1955 (84.9%)                  | 2043 (72.7%)        | 637 (72.6%)          | 1034 (75.6%)         |                      | <.001          |
| **Education level**         |                   |                                 |                     |                      |                      |                      | <.001          |
| Illiterate                  | 1406 (28.0%)      | 501 (21.8%)                   | 905 (33.2%)         | 142 (29.5%)          | 327 (37.3%)          | 436 (31.9%)          |                  |
| Primary school              | 2121 (42.2%)      | 1033 (44.9%)                  | 1088 (41.6%)        | 215 (44.6%)          | 340 (38.8%)          | 533 (39.0%)          |                  |
| Middle school               | 1228 (24.4%)      | 622 (27.0%)                   | 606 (22.2%)         | 93 (19.3%)           | 168 (19.2%)          | 345 (25.2%)          |                  |
| High school or above        | 248 (4.9%)        | 137 (5.9%)                    | 111 (4.1%)          | 30 (6.2%)            | 32 (3.6%)            | 49 (3.6%)            |                  |
| **Number of chronic diseases** |                 |                                 |                     |                      |                      |                      | <.001          |
| None                        | 1290 (25.6%)      | 651 (28.3%)                   | 639 (23.4%)         | 129 (26.8%)          | 184 (21.0%)          | 326 (23.8%)          |                  |
| Single                      | 1956 (38.9%)      | 851 (37.0%)                   | 1105 (40.5%)        | 186 (38.6%)          | 349 (39.8%)          | 570 (41.7%)          |                  |
| multiple                    | 1780 (35.4%)      | 799 (34.7%)                   | 981 (36.0%)         | 167 (34.6%)          | 344 (39.2%)          | 470 (34.4%)          |                  |
| **Smoking**                 |                   |                                 |                     |                      |                      |                      | <.001          |
| Current smoker              | 687 (13.7%)       | 403 (17.5%)                   | 284 (10.4%)         | 56 (11.6%)           | 90 (10.3%)           | 138 (10.1%)          |                  |
| Former smoker               | 524 (10.4%)       | 265 (11.5%)                   | 259 (9.5%)          | 48 (10.0%)           | 75 (8.6%)            | 136 (9.9%)           |                  |
| Never smoker                | 3811 (75.8%)      | 1633 (70.9%)                  | 2178 (79.9%)        | 378 (78.4%)          | 707 (80.6%)          | 1093 (79.9%)         |                  |
| **Alcohol drinking**        |                   |                                 |                     |                      |                      |                      | <.001          |
| Current alcohol drinker     | 1385 (27.5%)      | 644 (28.0%)                   | 741 (27.2%)         | 124 (25.7%)          | 192 (21.9%)          | 425 (31.1%)          |                  |
| Former alcohol drinker      | 244 (4.9%)        | 127 (5.5%)                    | 117 (4.3%)          | 21 (4.4%)            | 40 (4.6%)            | 56 (4.1%)            |                  |
| Never alcohol drinker       | 3386 (67.3%)      | 1525 (66.2%)                  | 1861 (68.2%)        | 335 (69.5%)          | 640 (73.0%)          | 886 (64.8%)          |                  |
| **Tea drinking**            |                   |                                 |                     |                      |                      |                      | .008            |
| Current tea drinker         | 590 (11.7%)       | 308 (13.4%)                   | 282 (10.3%)         | 62 (12.9%)           | 73 (8.3%)            | 147 (10.7%)          |                  |
| Former tea drinker          | 119 (2.4%)        | 52 (2.3%)                     | 67 (2.5%)           | 11 (2.3%)            | 21 (2.4%)            | 35 (2.6%)            |                  |
| Never tea drinker           | 4278 (85.0%)      | 1928 (83.7%)                  | 2350 (86.2%)        | 405 (84.0%)          | 772 (88.0%)          | 1173 (85.7%)         |                  |
| **Sleep quality**           |                   |                                 |                     |                      |                      |                      | .009            |
| Very good                   | 3326 (66.1%)      | 1532 (66.5%)                  | 1794 (65.8%)        | 322 (66.8%)          | 564 (64.3%)          | 908 (66.4%)          |                  |
| Fairly good                 | 1006 (20.0%)      | 458 (19.9%)                   | 548 (20.1%)         | 98 (20.3%)           | 203 (23.1%)          | 247 (18.1%)          |                  |
| Fairly bad                  | 219 (4.4%)        | 77 (3.3%)                     | 142 (5.2%)          | 22 (4.6%)            | 47 (5.4%)            | 73 (5.3%)            |                  |

\(^a\)Normal group: PP < 65 mmHg.
\(^b\)Wide PP group: PP ≥ 65 mmHg.
\(^c\)LSLD: PP ≥ 65 & SBP ≤ 140 & DBP ≤ 75 mmHg.
\(^d\)HSLD: PP ≥ 65 & SBP ≥ 140 & DBP ≤ 75 mmHg.
\(^e\)HSHD: PP ≥ 65 & SBP ≥ 140 & DBP ≥ 75 mmHg.
\(^f\)\(p\)-Value* showed the statistical difference between normal group and LSLD, HSLD, HSHD groups.
demographic factors (age, gender, body height, marital status, educational level), health-related factors (BMI, number of chronic diseases), lifestyle factors (smoking, alcohol drinking, tea drinking, sleep quality) and wide PP, including different types of wide PP groups (LSLD, HSLD, HSHD). The findings revealed that the median value of SBP, DBP, PP in 5030 elderly participants were 141 mmHg, 75 and 66 mmHg. We also found that people in PP \(\geq 65\) mmHg group accounted for more than half proportion in the elderly. Among the three different types of wide PP, the HSHD type accounted for the highest proportion of about 50%, and the LSLD type was the least, about 17.7%. Compared to
FIGURE 2 ORs (95% CIs) for demographic factors, health-related factors and lifestyle factors between the normal group and LSLD, HSLD, HSHD groups (LSLD: PP $\geq 65$ & SBP $\leq 140$ & DBP $\leq 75$ mmHg; HSLD: PP $\geq 65$ & SBP $\geq 140$ & DBP $\leq 75$ mmHg; HSHD: PP $\geq 65$ & SBP $\geq 140$ & DBP $\geq 75$ mmHg).
### TABLE 2  Results of subgroup analyses for lifestyles and wide PP

| Lifestyle factors | Male (n = 2460) | Female (n = 2570) |
|-------------------|-----------------|-------------------|
|                   | Normal group¹(n = 1276) | Wide PP group²(n = 1184) | Normal group¹(n = 1027) | Wide PP group²(n = 1543) |
|                   | OR (95%CI) | OR (95%CI) | OR (95%CI) | OR (95%CI) |
| **Smoking**       |             |             |             |             |
| Never smoker      | 1.00(ref.) | 1.00(ref.) | 1.00(ref.) | 1.00(ref.) |
| Former smoker     | 1.00(ref.) | .92 (.73,1.17) | 1.00(ref.) | .46 (.02,12.53) |
| Current smoker    | 1.00(ref.) | .77 (.62,95) | 1.00(ref.) | 1.30 (.26,9.68) |
| **Alcohol drinking** |             |             |             |             |
| Never drinker     | 1.00(ref.) | 1.00(ref.) | 1.00(ref.) | 1.00(ref.) |
| Former drinker    | 1.00(ref.) | 1.00 (.70,1.42) | 1.00(ref.) | .67 (.34,134) |
| Current drinker   | 1.00(ref.) | 1.58 (.131,1.91) | 1.00(ref.) | .89 (.70,11.4) |
| **Tea drinking**  |             |             |             |             |
| Never tea drinker | 1.00(ref.) | 1.00(ref.) | 1.00(ref.) | 1.00(ref.) |
| Former tea drinker| 1.00(ref.) | 1.30 (.82,2.07) | 1.00(ref.) | .81 (.28,2.40) |
| Current tea drinker| 1.00(ref.) | .88 (.70,1.10) | 1.00(ref.) | 1.19 (.76,1.91) |
| **Sleep quality** |             |             |             |             |
| Very good         | 1.00(ref.) | 1.00(ref.) | 1.00(ref.) | 1.00(ref.) |
| Fairly good       | 1.00(ref.) | .83 (.66,1.05) | 1.00(ref.) | .98 (.80,1.20) |
| Fairly bad        | 1.00(ref.) | 1.15 (.65,2.04) | 1.00(ref.) | 1.40 (.99,2.02) |

¹Normal group: PP < 65 mmHg.
²Wide PP group: PP ≥ 65 mmHg.

This age that men’s and women’s SBP began to differ, with women still increasing dramatically but men not,²⁶,²⁸ so women’s PP usually would be wider than men. Body height might influence the transmission of reflected waves, thus affecting the PP finally, larger body height was less prone to have HSLD type wide PP. People not in marriage were more likely to develop HSHD type wide PP. We suspected that it might cause by lack of care and supervision from a spouse. These old people were more likely to have bad lifestyle habits, ignore some chronic diseases, be lack of treatment or do not take medication regularly for hypertension. Education played protective roles in the HSLD and HSHD groups, which was consistent with the conclusion of previous studies,²⁹ because both two groups were hypertensive patients and a certain level of education helped them to know about this chronic disease, understand its harm, and seek social help for treatment more easily.

With regard to health-related factors, many studies had pointed out that overweight and obesity was a risk factor for hypertension patients.³⁰,³¹ In this study, we used BMI to evaluate overweight or obesity of participants. Interestingly, we found that the OR value of BMI was less than 1.0 in the LS LD group, indicating that the elderly with low SBP and DBP but still wide PP was generally slim, and gaining weight might be a beneficial behavior for them to control PP. Having single or multiple chronic diseases had positive associations in LS LD and HSHD groups but no statistical relationship in LSLD group. However, hypertension was included in chronic diseases in the interview, and hypertension had a strong correlation with HSLD and HSHD groups, so the casual relationship between number of chronic diseases and different types of wide PP was uncertain.

Regarding lifestyle factors, only current smoker was found to be negatively associated with the HSHD group, contrary to what we usually thought of smoking as a risk factor for hypertension. Nonetheless, a cross-sectional study of the association between smoking and blood pressure in men aged 20–80 years in Inner Mongolia also found that the adjusted blood pressure was lower in current smokers versus non-smokers and former smokers, meanwhile the adjusted PP tend to be decreased steadily as the pack/years increased in current smokers.³³ Some studies have conducted that smoking can cause acute blood pressure increase,³⁴ but the effect on PP was unclear and the long-term effects on blood pressure were also inconclusive. In our study, current alcohol drinker was positively correlated with HSHD group. We all know that heavy alcohol intake was a risk factor of hypertension. However, some prospective studies conducted that moderate alcohol intake was beneficial.³⁵,³⁶ Meanwhile a meta-analysis had pointed out that reducing alcohol intake could decrease blood pressure in participants who drank six or more drinks per day if they reduced their intake by about 50%.³⁷ Consequently, more evidence was needed to clarify the association of daily alcohol intake and wide PP. We had not found association between tea drinking and wide PP, but it had been reported that moderate drinking of green tea is a protective factor for hypertension patients. Some laboratory studies had shown that tea and its secondary metabolites played important roles in relaxing smooth muscle contraction, enhancing endothelial nitric oxide synthase activity,
5 | CONCLUSIONS

Our study provided evidence that blood pressure in the elderly population was different from general population, and half of the elderly had wide PP, mostly HSHD type wide PP. In addition, we explored the influencing factors of different types of wide PP, we found age, gender, body height, marital status, education level, chronic diseases, BMI, smoking and alcohol drinking had different associations with different types wide PP. Future prospective studies were required to prove the mechanism between these factors and increased risk of wide PP (supplementary materials).

AUTHOR CONTRIBUTIONS

Mengling Tang and Honglei Dai designed the study. Dandan Yang and Jie Chen processed data, performed statistical analysis and drafted the manuscript. Tingting Zhang, Yaoyao Lin, Xuecheng Yao, Lin Meng, Fanjia Guo and Kun Chen carefully revised the intellectual content.

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CONFLICTS OF INTEREST

The authors declare that they have no potential conflicts of interest.

PATIENT CONSENT STATEMENT

Written informed consents were obtained from all participants before enrolling in the study.

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REFERENCES

1. Oliveros E, Patel H, Kyung S, et al. Hypertension in older adults: assessment, management, and challenges. Clin Cardiol. 2020;43(2):99-107.
2. Kearney PM, Whelton R, Reynolds K, et al. Global burden of hypertension: analysis of worldwide data. Lancet. 2005;365(9455):217-223.
3. Whelton PK, Carey RM, Aronow WS, et al. 2017 ACC/AHA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA guideline for the prevention, detection, evaluation, and management of high blood pressure in adults: a report of the American college of cardiology/American heart association task force on clinical practice guidelines. J Am Coll Cardiol. 2018;71(19):e127-e248.
4. Chowdhury EK, Ernst ME, Nelson M, et al. Impact of the 2017 American heart association and American college of cardiology hypertension guideline in aged individuals. J Hypertens. 2020;38(12):2527-2536.
5. Franklin SS, Wt Gustin, Wong ND, et al. Hemodynamic patterns of age-related changes in blood pressure. The Framingham heart study. Circulation. 1997;96(1):308-315.
6. Homan TD, Bordes S, Cichowski E. Physiology, Pulse Pressure. StatPearls Publishing LLC. 2022. StatPearls. Treasure Island (FL): StatPearls Publishing Copyright ©.
7. Geng TT, Talaei M, Jafar TH, Yuan JM, Koh WP. Pulse pressure and the risk of end-stage renal disease among chinese adults in Singapore: the Singapore Chinese Health Study. J Am Heart Assoc. 2019;8(23):e033282.
8. Wang P, Li Y, Liu X, et al. Independent and cumulative effects of resting heart rate and pulse pressure with type 2 diabetes mellitus in Chinese rural population. Sci Rep. 2017;7(1):2625.
9. Okada K, Iso H, Cui R, Inoue M, Tszugane S. Pulse pressure is an independent risk factor for stroke among middle-aged Japanese with normal systolic blood pressure: the JPHC study. J Hypertens. 2011;29(2):319-324.
10. Georgakis MK, Gill D, Malik R, et al. Genetically predicted blood pressure across the lifespan: differential effects of mean and pulse pressure on stroke risk. Hypertension. 2020;76(3):953-961.
11. Jung Y, Choi DW, Park S, Jang SL, Park EC. Association between pulse pressure and onset of dementia in an elderly Korean population: a cohort study. Int J Environ Res Public Health. 2020;17(5):1657.
12. Lorenzo C, Aung K, Stern MP, Haffner SM. Pulse pressure, prehypertension, and mortality: the san Antonio heart study. Am J Hypertens. 2009;22(11):1219-1226.
13. Franklin SS, Gokhale SS, Chow VH, et al. Does low diastolic blood pressure contribute to the risk of recurrent hypertensive cardiovascular disease events. The Framingham Heart Study Hypertension. Hypertension. 2015;65(2):299-305.
14. Mancusi C, Losi MA, Izzo R, et al. Higher pulse pressure and risk for cardiovascular events in patients with essential hypertension: the Campania Salute Network. Eur J Prev Cardiol. 2018;25(3):235-243.
15. Warren J, Nanayakkara S, Andrianopoulos N, et al. Impact of pre-procedural blood pressure on long-term outcomes following percutaneous coronary intervention. J Am Coll Cardiol. 2019;73(22):2846-2855.

16. Hall JE, do Carmo JM, da Silva AA, Wang Z, Hall ME. Obesity-induced hypertension: interaction of neurohumoral and renal mechanisms. Circ Res. 2015;116(6):991-1006.

17. Titze J, Luft FC. Speculations on salt and the genesis of arterial hypertension. Kidney Int. 2017;91(6):1324-1335.

18. Dikalov S, Itani H, Richmond B, et al. Tobacco smoking induces cardiovascular mitochondrial oxidative stress, promotes endothelial dysfunction, and enhances hypertension. Am J Physiol-Heart C. 2019;316(3):H639-H646.

19. Fuchs FD, Fuchs SC. The effect of alcohol on blood pressure and hypertension. Curr Hypertens Rep. 2021;23(10):42.

20. Börjesson M, Onerup A, Lundqvist S, Dahlöf B. Physical activity and exercise lower blood pressure in individuals with hypertension: narrative review of 27 RCTs. Brit J Sport Med. 2016;50(6):356.

21. Palagini L, Bruno RM, Gemignani A, et al. Sleep loss and hypertension: a systematic review. Curr Pharm Design. 2013;19(13):2409-2419.

22. Buysse DJ, Reynolds CF, 3rd, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh sleep quality index: a new instrument for psychiatric practice and research. Psychiat Res. 1989;28(2):193-213.

23. National guideline for hypertension management in China (2019). Zhonghua xin xue guan bing za zhi. 2020;48(1):10-46.

24. Tsai TY, Cheng HM, Chuang SY, et al. Isolated systolic hypertension in Asia. J Clin Hypertens. 2021;23(3):467-474.

25. Safar ME. Arterial aging–hemodynamic changes and therapeutic options. Nat Rev Cardiol. 2010;7(8):442-449.

26. Li Y, Jiang B, Keehn L, et al. Hemodynamic mechanism of the age-related increase in pulse pressure in women. Hypertension. 2019;73(5):1018-1024.

27. Climie RE, Bruno RM, Hametner B, Mayer CC, Terentes-Printzios D. Vascular age is not only atherosclerosis, it is also arteriosclerosis. J Am Coll Cardiol. 2020;76(2):229-230.

28. Avolio AP, Kuznetsova T, Heyndrickx GR, Kerkhof PLM, Li JK. Arterial flow, pulse pressure and pulse wave velocity in men and women at various ages. Adv Exp Med Biol. 2018;1065:153-168.

29. Matricciani LA, Paquet C, Howard NJ, et al. Investigating individual- and area-level socioeconomic gradients of pulse pressure among normotensive and hypertensive participants. Int J Env Res Pub He. 2013;10(2):571-589.

SUPPORTING INFORMATION
Additional supporting information can be found online in the Supporting Information section at the end of this article.

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