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ORIGINAL ARTICLE

# Adherence to a healthy lifestyle and a DASH-style diet and risk of hypertension in Chinese individuals

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**Several modifiable risk factors have been shown to lower blood pressure, but little is known about their combined risk in Chinese individuals. In this prospective cohort study, we followed 2751 subjects aged 18–60 years in the China Health and Nutrition Survey who were free of diagnosed hypertension, cardiovascular disease, diabetes or cancer at baseline in 2000. The associations between each of the risk factors and the risk of developing incident hypertension were analyzed by gender. The three low-risk factors for hypertension were a body mass index (BMI) between 18.5 and 24, a moderate or heavy physical activity level ⩾0.5 h per day and a high score on the Dietary Approaches to Stop Hypertension (DASH) diet. Low-risk factors were combined to assess their effects on the risk of hypertension. During the 11-year follow-up, we documented 1147 cases of hypertension. Three risk factors were independently associated with the risk of hypertension even after adjustment for age, alcohol intake and smoking status. Adopting all three low-risk lifestyle factors (normal BMI, DASH-style diet and physical activity) could prevent 38% (95% confidence interval (CI), 19–53%) of new hypertension cases among women and 43% (95% CI, 25–57%) of new hypertension cases among men. Adherence to a healthy lifestyle and a DASH-style diet was associated with a lower risk of hypertension.**
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**Keywords:** Chinese people; CHNS; lifestyle

## INTRODUCTION

Hypertension is one of the most important risk factors for cardiovascular disease, accounting for nearly 45% of cardiovascular disease morbidity and mortality globally.[1] In China, the prevalence of hypertension in adults has increased from 14.5% to 21.4% from 1991 to 2009, respectively.[2] Given this epidemic of hypertension in China, only 22.8% of individuals with hypertension were treated; only 6.1% of those had their blood pressure (BP) controlled in 2009.[2] Many modifiable risk factors for hypertension have been studied independently, including being obese,[3] not participating in physical inactivity[4] and having an unhealthy diet.[5] The effects of interventions that modify one or several of these factors have been documented.[6,7] Compared with the costly pharmacologic management of hypertension, lifestyle and dietary interventions that focus on a combination of modifiable risk factors can prevent hypertension in a cost-effective way. Although a body of evidence on the combined effects of lifestyle risk factors on hypertension has been reported in Western populations,[8] data for a Chinese population are still limited. We, therefore, investigated the relationship between combinations of low-risk lifestyle factors and the risk of developing hypertension using data from an ongoing prospective cohort study in China, the China Health and Nutrition Survey (CHNS).

## METHODS

### Study design and subjects

The CHNS is a large-scale, longitudinal survey that was designed to explore how the health and nutritional status of the Chinese population has been affected by social and economic changes.[9] A multistage, random cluster process was used to draw the sample surveyed in each of the following provinces from northeast to southwest: Heilongjiang, Liaoning, Jiangsu, Shandong, Henan, Hubei, Hunan, Guizhou and Guangxi. Information on age, gender, region, body mass index (BMI) and BP measurements was collected. The sampling design has been fully described elsewhere.[9]

The CHNS surveys were conducted in 1989, 1991, 1993, 1997, 2000, 2004, 2006, 2009 and 2011. Because of the high quality of data from 2000, it was defined as the baseline year. A total of 11 972 subjects participated in the CHNS in 2000. Of these subjects, 5742 were excluded for the following exclusive reasons at baseline in 2000: (1) the subject was younger than 18 or older than 60 years($n=4167$); (2) the subject had missing average systolic blood pressure (SBP) or diastolic blood pressure data (if a subject had two or three measurements, we used the average of the measurements, and if a subject had only one measurement, then we used that measurement) ($n=631$); (3) the subject was identified to have hypertension in the baseline survey ($n=2055$); (4) the subject took antihypertensive medications ($n=455$); or (5) the subject had an existing diagnosis of diabetes ($n=129$), myocardial infarction ($n=49$) or apoplexy ($n=66$). Of the remaining 6230 subjects, 44.2% participated in all

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five successive follow-up surveys (2000–2011) with valid data, leading to a study population of 2751 subjects aged 18–60 years at baseline. Compared with the subjects ($n=2751$), those who did not complete the study ($n=3479$) were, on average, younger (36 *vs.* 42 years), were more often men (49.0% *vs.* 42.3%), had a slightly lower BMI (22.4 *vs.* 22.7 kg m$^{-2}$) and performed moderate or heavy physical activity time less often (3.4 *vs.* 3.8 h per day) ($P<0.05$ for all comparisons), while there were no significant differences in average BP (112.5/73.9 *vs.* 113.0/74.0 mm Hg) and Dietary Approaches to Stop Hypertension (DASH) score (20.4 *vs.* 20.5) between non-completers and completers ($P>0.05$). Moreover, according to the methodology described by Hildrum *et al.*[10], we tested for the effect modifications of sex and age by incorporating interaction terms into the models.[10,11] However, we found no interaction between age or sex and the association between DASH-style diet/BMI/physical activity and hypertension ($P>0.10$ for all interactions) (data not shown). Therefore, we did not expect non-completers to bias our findings.[11] We defined hypertension as having an average SBP $\geqslant$ 140 mm Hg, an average diastolic blood pressure $\geqslant$ 90 mm Hg, currently undergoing treatment with an antihypertensive medication, or having received a previous diagnosis by a physician.

## Dietary data collection and definition

Diet data were collected at the household level using weighing methods and at the individual level using three consecutive 24-h dietary recalls[12,13] on the same three consecutive days. All the foods and condiments that were in the home inventory, purchased from markets and picked from gardens were carefully recorded and measured at the start of the first 24-h dietary recall and at the end of the last 24-h dietary recall in the survey. The days of the 24-h dietary recall were selected randomly from Monday to Sunday in each community. Dietary intake (for example, vegetables and meat) at the individual level was surveyed by 24-h recalls by asking the individuals to report all food consumed each day while they were away from home and at-home. On the same three consecutive days, we directly and accurately weighed intakes of condiments (that is, salt, soy sauce and monosodium glutamate) at the household level, estimated salt intake based on the consumption of condiments according to the Chinese food composition table (FCT)[14] and allocated a proportion of salt consumed at the household level to each individual based on their meal consumption frequency.

To evaluate the overall dietary quality,[15] a DASH score was calculated based on the dietary data. The details of this score can be found elsewhere.[16] In brief, the DASH score recommends a high intake of five food components: fruits, vegetables, nuts and legumes, low-fat dairy products and whole grains; it also recommends a low intake of three food components: sodium, sweetened beverages, and red and processed meats.

Each subject's dietary data were collected at baseline in 2000, and then the dietary data were updated with every survey during the period from 2000 to 2011. To obtain the best estimate of long-term dietary intake, we used the cumulative-update method,[17] which takes the average of all previous dietary data. For each of the components, men and women were separately classified into quintiles according to their cumulative mean intake. A point from 1 to 5 was given according to the subject's sex-specific quintile ranking for the eight food components, making the total score range from 8 to 40. Of the 2751 subjects in our final sample, 88.6% did not consume low-fat dairy products, 75.3% did not consume nuts and 58.6% did not consume fruits (those who did not consume the component were assigned 1 point, the lowest quarter was assigned 2 points and the fourth quarter was assigned 5 points). The component scores for vegetables and whole grains were assigned according to the participant's quintile ranking (that is, quintile 1 was assigned 1 point and quintile 5 was assigned 5 points). For salt, red and processed meats, and sweetened beverages, a low intake was desired (the lowest quintile was assigned a score of 5 points and the highest quintile was assigned a score of 1 point, except for sweetened beverages). Of the subjects, 79.5% did not consume sweetened beverages (those who did not consume the component were assigned 5 points, the lowest quarter was assigned 4 points and the fourth quarter was assigned 1 point).

## Non-dietary data collection

Physical activity was defined as the combination of occupational activities, home activities and leisure-time physical activities. On the basis of the model proposed by Pate *et al.*[18] that classifies the metabolic equivalent intensity of physical activities, moderate physical activity was activity performed at an intensity from 3 to 6 metabolic equivalents (vigorous physical activity, $>6$ metabolic equivalents). We collected the amount of time that each subject spent doing moderate or vigorous physical activities ($\geqslant$3 metabolic equivalents), including carrying small children, mopping, running and performing other aerobic activities.[19]

The data on demographics (age, sex and living area), BP, BMI (calculated as weight in kilograms divided by height in meters squared), lifestyle (ever smoking, alcohol intake) and the use of medications were collected by trained and certified health professionals through interviews and physical examinations. For smoking, the subjects were divided into four groups according to their smoking status (non-, ex-, current smoking, heavy smoking (those who smoked $\geqslant$ 15 cigarettes per day)). For drinking, the subjects were divided into five categories according to their alcohol consumption (non-drinker, ex-drinker, 0.1 ~ 10, 10.1 ~ 25.0, $>$25 g per day).

After at least a 10-min rest, arterial BP was measured on the right arm (~25 mm above the elbow) in a sitting position using a mercury sphygmomanometer with the cuff maintained at the heart level. Blood pressure was measured three times during one visit, and the average of three reading was used in the analysis.

## Definition of low-risk groups

The DASH diet has been shown in randomized controlled trails to lower BP,[20] and in our study, the subjects whose DASH scores were in the top quintile (quintile 5) had a significantly lower hazard ratio (HR) for incident hypertension than subjects in the reference group. Consistent with this result, the subjects with high DASH scores were in quintile 5 and were classified as having a low-risk diet.

Initially, we considered defining the low-risk group according to five modifiable risk factors: (DASH-style) diet, BMI, physical activity, smoking and alcohol. However, smoking and drinking were not chosen for the present analysis because smoking was not associated with hypertension and light-to-moderate drinking increased the risk of hypertension in men based on the results of this study as shown in Table 1. Although light-to-moderate alcohol consumption decreased hypertension risk in women based on the results shown in Table 1, previous observational studies have demonstrated that modest alcohol use was associated with a lower risk of hypertension in women.[21] However, the estimates in our study were somewhat imprecise because few women were in the light-to-moderate alcohol categories.

On the basis of the weight criteria for adults in China,[22] a BMI $<24$ but $>18.5$ is defined as a normal weight, a BMI $>24$ is defined as overweight and a BMI $>28$ is defined as obese. In this study, normal weight was selected as the low-risk category for BMI.

Physical activity lowers BP and decreases hypertension risk,[23] and in our study, performing moderate or heavy physical activities (metabolic equivalent $\geqslant$3) for at least 0.5 h per day was defined as the low-risk physical activity.

## Statistical analysis

The person-time for each subject was calculated from 2000 to either the date that hypertension was first diagnosed or 2011, whichever came first. For those who developed hypertension, the date of hypertension onset was assumed to be the day that hypertension was diagnosed.

Separate analyses were performed for women and men. The associations between each of the five modifiable risk factors and the risk of developing incident hypertension were analyzed by gender. A Cox proportional hazards regression was used to estimate the HR of incident hypertension and its 95% confidence interval (CI) for each risk factor. The multivariable models simultaneously adjusted for all these modifiable risk factors as well as for the potential confounders, including age, income, employment status, education, province and urban or rural region. We calculated the cumulative means for the time spent performing physical activities and for the dietary data. For all other risk variables and covariates apart from diet and physical activity, we used the most recent information.[17]

Then, we divided these factors into low- and high-risk categories according to the aforementioned methodology ('Definition of Low-risk Groups' section):

**Table 1 Distribution of modifiable risk factors and multivariable HR of hypertension among 2751 Subjects in CHNS, 2000–2011**

| *Risk factor* | *No. of subjects*[a] | *Person-years (%)* | *Multivariable HR (95% CI)*[b] |
|---|---|---|---|
| *Male (N = 1164)* | | | |
| Quintile of DASH score | | | |
| 1 (<18) | 146 | 1225 (11.7%) | 1 (Reference) |
| 2 (18–20) | 192 | 1737 (16.6%) | 0.83 (0.59–1.18) |
| 3 (20–22) | 253 | 2283 (21.9%) | 0.75 (0.54–1.04) |
| 4 (22–24) | 239 | 2192 (20.9%) | 0.63 (0.45–0.89)* |
| 5 (⩾24) | 329 | 3006 (28.8%) | 0.62 (0.45–0.85)* |
| Moderate or heavy physical activity, h per day | | | |
| <0.5 | 170 | 1324 (12.7%) | 1 (Reference) |
| 0.5–1.0 | 83 | 754 (7.2%) | 0.53 (0.35–0.80)* |
| 1.0–2.0 | 141 | 1287 (12.3%) | 0.44 (0.31–0.64)* |
| ⩾2.0 | 770 | 7098 (67.8%) | 0.36 (0.27–0.47)* |
| BMI, kg m$^{-2}$ | | | |
| <18.5 | 77 | 720 (6.9%) | 0.83 (0.53–1.30) |
| 18.5–24 | 646 | 5985 (57.2%) | 1 (Reference) |
| 24–28 | 345 | 2997 (28.6%) | 1.53 (1.23–1.89)* |
| ⩾28 | 96 | 761 (7.3%) | 2.15 (1.55–2.98)* |
| Smoking (cigarettes per day) | | | |
| Never smoked | 388 | 3510 (34.0%) | 1 (Reference) |
| Former smoker | 79 | 692 (6.7%) | 1.11 (0.75–1.66) |
| 1–14 | 232 | 2045 (19.8%) | 1.12 (0.85–1.46) |
| ⩾15 | 448 | 4068 (39.4%) | 0.92 (0.73–1.16) |
| Alcohol intake, g per day | | | |
| 0 | 201 | 1769 (16.9%) | 1 (Reference) |
| Ex-drinker | 271 | 2511 (24.0%) | 0.94 (0.69–1.28) |
| 0.1 ~ 10.0 | 212 | 1905 (18.3%) | 1.00 (0.72–1.38) |
| 10.1–25.0 | 200 | 1871 (17.9%) | 0.80 (0.57–1.13) |
| >25.0 | 280 | 2407 (23.0%) | 1.42 (1.05–1.93)* |
| *Female (N = 1587)* | | | |
| Quintile of DASH score | | | |
| 1 (<18) | 239 | 2220 (14.6%) | 1 (Reference) |
| 2 (18–20) | 252 | 2388 (15.7%) | 0.85 (0.62–1.16) |
| 3 (20–22) | 327 | 3127 (20.6%) | 0.82 (0.61–1.11) |
| 4 (22–24) | 334 | 3217 (21.2%) | 0.79 (0.59–1.07) |
| 5 (⩾24) | 433 | 4222 (27.8%) | 0.71 (0.53–0.94)* |
| Moderate or heavy physical activity, h per day | | | |
| <0.5 | 159 | 1308 (8.6%) | 1 (Reference) |
| 0.5–1.0 | 172 | 1662 (10.9%) | 0.43 (0.29–0.61)* |
| 1.0–2.0 | 257 | 2559 (16.9%) | 0.40 (0.28–0.55)* |
| ⩾2.0 | 999 | 9655 (63.6%) | 0.34 (0.26–0.46)* |
| BMI, kg m$^{-2}$ | | | |
| <18.5 | 102 | 988 (6.5%) | 0.83 (0.55–1.25) |
| 18.5–24 | 807 | 7940 (52.3%) | 1 (Reference) |
| 24–28 | 528 | 4885 (32.2%) | 1.51 (1.24–1.82)* |
| ⩾28 | 150 | 1371 (9.0%) | 1.64 (1.23–2.19)* |
| Smoking (cigarettes per day) | | | |
| Never smoked | 1517 | 14566 (96.1%) | 1 (Reference) |
| Former smoker | 9 | 88 (0.6%) | 0.82 (0.28–2.41) |
| 1–14 | 32 | 282 (1.9%) | 1.01 (0.56–1.83) |
| ⩾15 | 26 | 215 (1.4%) | 1.71 (0.97–3.01) |
| Alcohol intake, g per day | | | |
| 0 | 1316 | 12513 (82.4%) | 1 (Reference) |
| Ex-drinker | 161 | 1583 (10.4%) | 0.82 (0.60–1.11) |
| 0.1 ~ 10.0 | 59 | 574 (3.8%) | 0.83 (0.50–1.36) |
| 10.1–25.0 | 31 | 330 (2.2%) | 0.39 (0.15–0.96)* |
| >25.0 | 20 | 184 (1.2%) | 1.16 (0.55–2.45) |

Abbreviations: BMI, body mass index; CI, confidence interval; CHNS, China Health and Nutrition Survey; DASH, Dietary Approaches to Stop Hypertension; HR, hazard ratio.
*$P$<0.05.
[a]The number of cases for each individual factor may not add up to 1164 or 1587 due to missing data on the individual factor.
[b]Adjusted for age, income, employment status, education, province, urban or rural, and for all of the factors that appear in the table.

DASH score (highest quintile *vs.* lower 4 quintiles); BMI (from 18.5 to 24 kg m$^{-2}$ *vs.* other levels of BMI); and moderate or heavy physical activity (⩾0.5 h per day *vs.* <0.5 h per day). Separate analyses were performed for women and men. The associations between the combinations of low-risk factors and incident hypertension were analyzed using Cox proportional hazards regression. Subjects with a high DASH score were compared with all other subjects after adjusting for age, income, employment status, education, province, urban or rural region, smoking, alcohol intake, BMI and moderate or heavy physical activity time. Then, subjects with a combination of two low-risk factors, including DASH score and BMI, were analyzed. Finally, subjects with a combination of three low-risk factors, including DASH score, BMI and moderate or heavy physical activity time, were compared with all other subjects. The hypothetical population attributable risk (PAR) was calculated for each of these analyses under the assumption that the observed associations were causal with the following standard equation:

$$\mathrm{PAR} = \{(\mathrm{HR} - 1) \times P_e\} \div \{([\mathrm{HR} - 1] \times P_e) + 1\}.$$

where $P_e$ is the exposed proportion.[8]

To obtain the best estimate of PAR, we calculated the PAR by using the observed HR (calculated from 2751 subjects) with a more representative population of those aged 18–60 years ($N$ = 6230) at baseline.

Finally, we combined the sex-specific results to analyze the associations between combinations of risk factors and multivariable HR for hypertension among all subjects.

All statistical tests were performed using SAS statistical software version 9.1 (SAS Institute, Cary, NC, USA). All $P$-values were 2-tailed; $P$<0.05 was considered statistically significant.

## RESULTS

Table 2 shows the baseline characteristics of the participants. At baseline, in 2000, the mean (s.d.) age of the population was 42 (9.3) years old, and the mean (s.d.) BMI was 22.7 (2.9) kg m$^{-2}$. During the 25 647 person-year follow-up, we documented 1147 cases of hypertension, and the incidence rate was 4.5 cases per 100 person-years. Subjects with a higher baseline SBP were more likely to be those with a higher baseline BMI, those who were older, or those who performed less physical activity per day.

To address whether a low-risk lifestyle was similarly associated with a lower hypertension risk between men and women, we stratified our analysis by gender. The multivariable adjusted associations between the five individual modifiable risk factors and incident hypertension are independently shown in Table 1 for men and women. Smoking was not significantly associated with incident hypertension in both men and women. However, after multivariable adjustment, the other four modifiable risk factors were associated with incident hypertension. Those who had a higher DASH score, who spent more time performing moderate or heavy physical activities per day and who had a normal BMI had a lower HR for incident hypertension regardless of gender. There was a dose–response relationship between the DASH score and the HR for incident hypertension; subjects with scores in the highest quintiles had a significantly lower HR than those with scores in the remaining quintiles for both men (0.62 (95% CI, 0.45–0.85)) and women (0.71 (95% CI, 0.53–0.94)). Men who performed 2 h per day of moderate or heavy physical activity had a HR for incident hypertension of 0.36 (95% CI, 0.27–0.47) relative to men who performed <0.5 h per day of moderate or heavy physical activity. Obese men had a HR for incident hypertension of 2.15 (95% CI, 1.55–2.98) relative to men who had a BMI <24 kg m$^{-2}$ but >18.5 kg m$^{-2}$. The association between alcohol intake and the risk of developing hypertension differed in men and women. We found that men in the highest level of alcohol intake (>25 g per day) had a HR for incident hypertension of 1.42 (95% CI, 1.05–1.93) relative to men who did not consume alcohol, with no evidence of benefit for those

**Table 2 Baseline characteristics of participants who were free of hypertension at baseline surveys**

| | *Male* | | *Female* | |
|---|---|---|---|---|
| | *Normal* (n = *496*) | *Prehypertension* (n = *668*) | *Normal* (n = *946*) | *Prehypertension* (n = *641*) |
| Age (years) | 41.7 ± 9.7[a] | 42.4 ± 9.6 | 40.6 ± 9.1 | 43.7 ± 8.7 |
| *Education*, n *(%)* | | | | |
| Primary or below | 180 (36.3%) | 242 (36.2%) | 511 (54.0%) | 374 (58.3%) |
| Junior high | 195 (39.3%) | 250 (37.4%) | 272 (28.8%) | 151 (23.6%) |
| Senior high | 78 (15.7%) | 112 (16.8%) | 95 (10.0%) | 61 (9.5%) |
| Vocational school | 30 (6.0%) | 35 (5.2%) | 33 (3.5%) | 33 (5.1%) |
| College or above | 10 (2.0%) | 22 (3.3%) | 18 (1.9%) | 9 (1.4%) |
| *Employment status*, n *(%)* | | | | |
| Employed | 451 (90.9%) | 574 (85.9%) | 780 (82.5%) | 490 (76.4%) |
| Unemployed | 43 (8.7%) | 90 (13.5%) | 164 (17.3%) | 150 (23.4%) |
| *Income (CNY)*, n *(%)* | | | | |
| 0–500 | 397 (80.0%) | 519 (77.7%) | 866 (91.5%) | 595 (92.8%) |
| 500–1000 | 74 (14.9%) | 123 (18.4%) | 70 (7.4%) | 42 (6.6%) |
| 1000–2000 | 22 (4.4%) | 21 (3.1%) | 7 (0.7%) | 4 (0.6%) |
| ⩾2000 | 3 (0.6%) | 5 (0.8%) | 3 (0.3%) | 0 (0.0%) |
| DASH score | 20.1 ± 3.5 | 20.5 ± 3.4 | 20.4 ± 3.4 | 20.9 ± 3.3 |
| *Whole grains (g per day)* | | | | |
| Quartile 1 | 0.0 | 33.3 | 0.0 | 16.7 |
| Quartile 2 | 100.0 | 100.0 | 83.3 | 100.0 |
| Quartile 3 | 200.0 | 333.3 | 191.7 | 300.0 |
| *Vegetables (g per day)* | | | | |
| Quartile 1 | 230.8 | 233.3 | 211.7 | 233.3 |
| Quartile 2 | 333.3 | 333.3 | 300.0 | 316.7 |
| Quartile 3 | 475.0 | 450.0 | 433.3 | 433.3 |
| *Salt (g per day)* | | | | |
| Quartile 1 | 8.0 | 7.6 | 7.0 | 6.5 |
| Quartile 2 | 11.8 | 10.9 | 10.2 | 9.8 |
| Quartile 3 | 17.7 | 16.8 | 14.6 | 15.3 |
| *Red and processed meats (g per day)* | | | | |
| Quartile 1 | 0.0 | 0.0 | 0.0 | 0.0 |
| Quartile 2 | 71.7 | 66.7 | 50.0 | 47.7 |
| Quartile 3 | 150.0 | 138.9 | 116.7 | 113.3 |
| *Fruits (g per day)*, n *(%)* | | | | |
| 0 | 445 (89.7%) | 600 (89.8%) | 823 (87.0%) | 572 (89.2%) |
| 0–50 | 9 (1.8%) | 11 (1.7%) | 21 (2.2%) | 13 (2.0%) |
| 50–100 | 18 (3.6%) | 19 (2.8%) | 36 (3.8%) | 23 (3.6%) |
| ⩾100 | 24 (4.8%) | 38 (5.7%) | 66 (7.0%) | 33 (5.2%) |
| *Low-fat dairy (g per day)*, n *(%)* | | | | |
| 0 | 483 (97.4%) | 647 (96.9%) | 916 (96.8%) | 620 (96.7%) |
| 0–100 | 8 (1.6%) | 8 (1.2%) | 13 (1.4%) | 3 (0.5%) |
| ⩾100 | 5 (1.0%) | 13 (2.0%) | 17 (1.8%) | 18 (2.8%) |
| *Nuts (g per day)*, n *(%)* | | | | |
| 0 | 447 (90.1%) | 606 (90.7%) | 861 (91.0%) | 593 (92.5%) |
| 0–30 | 18 (3.6%) | 27 (4.0%) | 48 (5.1%) | 23 (3.6%) |
| ⩾30 | 31 (6.3%) | 35 (5.2%) | 37 (3.9%) | 25 (3.9%) |
| *Alcohol intake (g per day)*, n *(%)* | | | | |
| 0 | 189 (38.1%) | 239 (35.8%) | 864 (91.3%) | 580 (90.5%) |
| 0–10 | 70 (14.1%) | 115 (17.2%) | 50 (5.3%) | 34 (5.3%) |

**Table 2 (Continued)**

| | *Male* | | *Female* | |
|---|---|---|---|---|
| | *Normal* (n = *496*) | *Prehypertension* (n = *668*) | *Normal* (n = *946*) | *Prehypertension* (n = *641*) |
| 10–25 | 96 (19.4%) | 110 (16.5%) | 16 (1.7%) | 13 (2.0%) |
| >25 | 141 (28.4%) | 204 (30.5%) | 16 (1.7%) | 14 (2.2%) |
| *Smoking (cigarettes per day),* n *(%)* | | | | |
| 0 | 173 (35.9%) | 228 (35.7%) | 905 (96.7%) | 606 (96.0%) |
| 1–14 | 120 (24.9%) | 157 (24.6%) | 20 (2.1%) | 16 (2.5%) |
| ⩾15 | 189 (39.2%) | 253 (39.7%) | 11 (1.2%) | 9 (1.4%) |
| Physical activity (h per day), mean ± s.d. | 4.3 ± 3.5 | 3.7 ± 3.6 | 3.8 ± 3.4 | 3.4 ± 3.6 |
| *Physical activity (h per day),* n *(%)* | | | | |
| <0.5 | 100 (20.2%) | 204 (30.5%) | 175 (18.5%) | 151 (23.6%) |
| 0.5–1.0 | 32 (6.5%) | 38 (5.7%) | 113 (12.0%) | 86 (13.4%) |
| 1.0–2.0 | 38 (7.7%) | 59 (8.8%) | 95 (10.0%) | 85 (13.3%) |
| ⩾2.0 | 326 (65.7%) | 367 (54.9%) | 563 (59.5%) | 319 (49.8%) |
| BMI (kg m$^{-2}$), mean ± s.d. | 21.8 ± 2.5 | 23.1 ± 2.9 | 22.3 ± 2.8 | 23.5 ± 3.2 |
| *BMI (kg m$^{-2}$), n (%)* | | | | |
| <18.5 | 33 (6.7%) | 29 (4.3%) | 64 (6.8%) | 34 (5.3%) |
| 18.5–24 | 374 (75.4%) | 416 (62.3%) | 648 (68.5%) | 339 (52.9%) |
| 24–28 | 81 (16.3%) | 183 (27.4%) | 204 (21.6%) | 221 (34.5%) |
| ⩾28 | 8 (1.6%) | 40 (6.0%) | 30 (3.2%) | 47 (7.3%) |
| SBP (mm Hg) | 106.6 ± 8.3 | 121.8 ± 7.3 | 104.8 ± 8.6 | 121.1 ± 8.1 |
| DBP (mm Hg) | 69.4 + 6.3 | 80.0 ± 5.1 | 68.2 ± 6.8 | 79.8 ± 4.9 |

Abbreviations: CNY, China Yuan; DASH, Dietary Approaches to Stop Hypertension; DBP, diastolic blood pressure; SBP, systolic blood pressure.
[a]Mean ± s.d. (all such values).

who consumed a light–moderate amount of alcohol ($P>0.05$). However, women who consumed a light–moderate amount of alcohol (10–25 g per day) had a HR for incident hypertension of 0.39 (95% CI, 0.15–0.96). For women who drank 25 g or more alcohol per day, there was a small but not significant increase in incident hypertension compared with non-drinkers.

The associations between the combinations of risk factors and hypertension were stratified by gender (Table 3). Specifically, among men, the hypothetical PARs ranged from 16% (95% CI, 0–30%) for one low-risk factor to 43% (95% CI, 25–57%) for three low-risk factors. Among women, the hypothetical PARs ranged from 14% (95% CI, − 2–28%) for one low-risk factor to 38% (95% CI, 19–53%) for three low-risk factors.

Table 4 shows the associations between the combinations of risk factors and the multivariable HR for hypertension among all subjects. Subjects with a DASH-style diet (in the highest quintile of DASH score) had a HR for incident hypertension of 0.85 (95% CI, 0.73–0.98). The hypothetical PAR was 12% (95% CI, 2–23%), suggesting that 12% of new-onset hypertension cases in this population could potentially be prevented if all subjects adopted this one low-risk factor of a DASH-style diet. The hypothetical PAR was 31% (95% CI, 18–43%) if the low-risk group further adopted a normal BMI (18.5–24 kg m$^{-2}$) and rose to 40% (95% CI, 27–50%) if the low-risk group further adopted a daily moderate or heavy physical activity (three low-risk factors total).

## DISCUSSION

In this population-based prospective cohort study of an adult Chinese population, we found that Chinese adults with low-risk combinations of modifiable lifestyle factors were associated with dramatic reduction in the incidence of hypertension during follow-up. Moreover, based on the gender-stratified model (Table 3), we found that the association between a low-risk lifestyle and lower hypertension was similar among men and women. Among women, having three low-risk factors (a DASH-type diet, normal BMI and daily moderate or heavy physical activity) was associated with a HR for incident hypertension of 0.60 (95% CI, 0.45–0.80); the corresponding hypothetical PAR was 38% (95% CI, 19–53%), which was similar to previous findings.[8]

BMI, physical activity, a DASH-type diet and alcohol consumption have been shown to be independently associated with a risk of incident hypertension or changes in BP in various studies. A higher BMI has been shown to be associated with a higher risk of incident hypertension.[24,25] Compared with those who lowered their BMI, males and females who gained ⩾2.4 kg m$^{-2}$ had a 1.68 or 1.42 times higher odds of becoming hypertensive, respectively.[24] Daniels *et al.*[26] reported the following predicted increases in SBP per unit increase in BMI (mm Hg per kg m$^{-2}$): 0.65 ± 0.04 mm Hg per kg m$^{-2}$ in whites and 0.52 ± 0.04 mm Hg per kg m$^{-2}$ in blacks ($P<0.001$). Higher physical activity levels also have been shown to be associated with a lower risk of incident hypertension. Subjects with low physical activity had a 1.27 times higher risk relative to subjects with high physical activity.[27] Hallal *et al.*[28] found that those who exceeded the 300-min moderate-to-vigorous physical activity threshold per week had a 2.6 mm Hg lower mean increase in diastolic blood pressure from 11 to 14 years old than those below the threshold. DASH-type diets, which are rich in fruits and vegetables but low in sweets, salt and high-fat protein sources, have been proven to lower BP. The longitudinal Chicago Western Electric Study found that men who consumed 0.5–1.5 cups per day compared with those who consumed <0.5 cups per day of fruits and vegetables were estimated to had a lower rise in SBP over 7 years ($P<0.05$).[29] One study demonstrated that mean SBP significantly decreased by 4.5 ± 7.5 mm Hg in response to decreased

**Table 3 Multivariable relative and hypothesized PARs of incident hypertension with different low-risk factors and stratified by gender**

| *No. of low-risk factors* | *No. (%) of subjects among 2751 subjects* | *No. of hypertension cases* | *Multivariable HR (95% CI)* | *No. (%) of subjects among 6230 subjects* | *PAR, % (95% CI)*[a] |
|---|---|---|---|---|---|
| *Male* | | | | | |
| Highest DASH quintile[b] | 329 (28.3) | 153 | 0.81[#] (0.65–1.01) | 577 (20.1) | 16 (0–30) |
| Highest DASH quintile, normal BMI (18.5–24 kg m$^{-2}$)[c] | 178 (15.3) | 71 | 0.62* (0.47–0.82) | 385 (13.4) | 35 (16–49) |
| The two factors above plus daily moderate or heavy physical activity[d] | 158 (13.6) | 60 | 0.54* (0.40–0.73) | 300 (10.5) | 43 (25–57) |
| *Female* | | | | | |
| Highest DASH quintile[b] | 433 (27.3) | 160 | 0.83[#] (0.68–1.02) | 629 (18.7) | 14 (–2–28) |
| Highest DASH quintile, normal BMI (18.5–24 kg m$^{-2}$)[c] | 225 (14.2) | 72 | 0.69* (0.53–0.91) | 380 (11.3) | 28 (8–44) |
| The two factors above plus daily moderate or heavy physical activity[d] | 212 (13.4) | 64 | 0.60* (0.45–0.80) | 297 (8.8) | 38 (19–53) |

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); CI, confidence interval; DASH, Dietary Approaches to Stop Hypertension. HR, hazard ratio; PAR, population attributable risks.
[#]$P<0.1$.
*$P<0.05$.
[a]Indicates the percentage of new hypertension cases in the population that would hypothetically not have occurred if all subjects had been in the low-risk group.
[b]Adjusted for age, income, employment status, education, province, rural or urban, smoking, alcohol use, BMI and physical activity.
[c]Adjusted for everything in footnote 'b' except BMI.
[d]Adjusted for everything in footnote 'b' except physical activity and BMI.

**Table 4 Multivariable relative and hypothesized PARs of incident hypertension with different low-risk factors**

| *No. of low-risk factors* | *No. (%) of subjects among 2751 subjects* | *No. of hypertension cases* | *Multivariable HR (95% CI)* | *No. (%) of subjects among 6230 subjects* | *PAR, % (95% CI)*[a] |
|---|---|---|---|---|---|
| Highest DASH quintile[b] | 762 (27.7) | 313 | 0.85[c] (0.73–0.98) | 1206 (19.4) | 12 (2–23) |
| Highest DASH quintile, normal BMI (18.5–24kg m$^{-2}$)[d] | 403 (14.7) | 143 | 0.66[c] (0.54–0.80) | 765 (12.3) | 31 (18–43) |
| The two factors above plus daily moderate or heavy physical activity[e] | 370 (13.5) | 124 | 0.58[c] (0.47–0.71) | 597 (9.6) | 40 (27–50) |

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); CI, confidence interval; DASH, Dietary Approaches to Stop Hypertension; HR, hazard ratio; PARs, population attributable risks.
[a]Indicates the percentage of new hypertension cases in the population that would hypothetically not have occurred if all subjects had been in the low-risk group.
[b]Adjusted for age, gender, income, employment status, education, province, rural or urban, smoking, alcohol use, BMI and physical activity.
[c]$P<0.05$.
[d]Adjusted for everything in footnote 'b' except BMI.
[e]Adjusted for everything in footnote 'b' except physical activity and BMI.

salt intake during the night.[30] Modest alcohol consumption was associated with a lower risk of hypertension and heavy alcohol consumption was associated with an increased risk of hypertension in women.[31] However, for men, a linear dose–response relationship was observed such that those consuming 50 g pure alcohol per day had a 1.57 higher risk and those consuming 100 g pure alcohol per day had a 2.47 higher risk than non-drinkers.[32] These findings support our results.

In our study, although we found that multiple low-risk factors were significantly associated with a low risk of hypertension, the subjects may not benefit from DASH-type diets unless they strongly adhere to the diet recommendations. Health benefits could also be gained from physical activity. Subjects who performed 30 min of moderate or heavy physical activity per day could benefit, and those who spent more time performing moderate-intensity physical activities were also likely to derive more health benefits. Smoking is a strong risk factor for cardiovascular disease, but our data did not clearly present evidence of a direct relationship between smoking and hypertension. Our data indicated that light alcohol consumption could significantly reduce the risk of hypertension in women, and this finding was consistent with the finding from an earlier study[31] that showed light-to-moderate alcohol consumption decreased hypertension risk in women and increased the risk in men. However, the estimates of our study were somewhat imprecise because there were only a few women in the light-to-moderate alcohol categories (Table 1). Thus, limiting alcohol intake should be advised for both men and women.

The limitations of the present study should be acknowledged. First, we did not have information about the subject's family history of hypertension and other residual confounders; thus, the adjustment might be not perfectly comprehensive. Second, it is possible that the diet data that were gathered using weighing methods in combination with three consecutive 24-h dietary recalls does not represent the real diet data throughout the year, and some subjects may have had their DASH scores misclassified. Third, we categorized lifestyle factors into low-risk and high-risk groups to simplify the analysis, but the associations between these factors and hypertension risk are continuous. However, increasing the number of categories for each of the three risk factors would exponentially increase the number of possible low-risk factors, thereby making the calculation and presentation of the data overly complex and underpowered. Finally, the rate of follow-up in the study was limited; however, we do not expect non-completers to bias the associations that we have observed.

## CONCLUSIONS

Although pharmacologic treatment of hypertension has been proven effective, our study supports that adherence to a low-risk diet and healthy lifestyle factors could prevent a substantial majority of incident hypertension cases in Chinese individuals. A decrease in SBP of

2 mm Hg would lower the risk of stroke mortality by ~10% and lower the risk of mortality from ischemic heart disease or other vascular causes by ~7% in middle age.[33] The prevention of hypertension would have major public health benefits.

## CONFLICT OF INTEREST

The authors declare no conflict of interest.

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