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ORIGINAL ARTICLE

Fruit and vegetable intake and the risk of arterial hypertension in China: A prospective cohort study

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Abstract

Background: Population-based epidemiological evidence regarding the association between fruit and vegetable intake and the incidence of hypertension is inconsistent. This prospective cohort study aimed to investigate the association between fruit and vegetable intake and the risk of new-onset hypertension.

Methods: Based on the project of Prediction for Atherosclerotic Cardiovascular Disease Risk in China (China-PAR), 58,981 Chinese adults without hypertension at baseline were included. Information on fruit and vegetable intake was collected using a food-frequency questionnaire. Cox proportional hazards models were performed to estimate the hazard ratios (HRs) and 95% confidence intervals (CIs) of incident hypertension.

Results: During 640,795 person-years of follow-up, 21,008 new cases of hypertension were recorded. Compared with participants in the lowest quintile (Q1) of total fruit and vegetable (TFV) intake, the HRs (95% CIs) of incident hypertension were 0.90 (0.86–0.95), 0.85 (0.81–0.90), 0.82 (0.78–0.86), and 0.83 (0.78–0.88) for the Q2 to Q5 group ($p_{trend} < 0.001$), respectively. In further analyses categorizing participants according to the recommended intake level (500 g/day), we found that increasing the intake of TFV, even though it was still insufficient for the recommendation, also had a protective

Zhi He and Yanhui Jia contributed equally to this study.

effect against the incident hypertension. When considering the intake of fruit or vegetable separately, we found similar trends as the TFV intake.
Conclusion: These results suggest that a higher intake of fruit and vegetable is beneficial for preventing hypertension in Chinese adults.

KEYWORDS
fruit and vegetable, hypertension, prospective study

Key points

- Inverse and nonlinear dose–response relationships existed between the intakes of total fruit and vegetable, fruit, and vegetable and the risk of new-onset hypertension.
- Sufficient intake of fruit and vegetable can significantly reduce the risk of new-onset hypertension.
- Small increases in the consumption of fruit and vegetable, even if still far below the recommended levels, could also reduce the risk of new-onset hypertension.

1 | INTRODUCTION

As a major risk factor for cardiovascular disease, high blood pressure (BP) remains the top cause of disease morbidity and mortality worldwide.[1] According to the China Hypertension Survey (2012–2015), 23.2% of Chinese adults (approximately 245 million) suffered from hypertension, while awareness, treatment, and control rates of hypertension were 46.9%, 40.7%, and 15.3%, respectively, which were still at a relatively low level.[2] In addition, another 435 million adults had high-normal BP according to the 2018 Chinese Guidelines for the Management of Hypertension.[2,3] Thus, it is imminent to pay attention to the prevention and control of hypertension.

Fruit and vegetable, as essential components of a healthy diet, are rich in dietary fiber, antioxidant compounds, and potassium (K^+), all of which could have beneficial health effects on the prevention and management of hypertension.[4–6] The Chinese Guideline on Healthy Lifestyle to Prevent Cardiometabolic Diseases recommends at least 500 g/day of total fruit and vegetable (TFV) intake, 200–350 g/day of fruit, and 300–500 g/day of vegetable.[7] However, the vegetable and fruit intakes are still at low levels, and the average daily intake of TFV and fruit in 2018 was only 483.9 and 114.8 g/day in Chinese adults,[8] respectively, lower than the recommendation stated above. According to the China National Nutrition Surveys, insufficient fruit and vegetable intake is an important risk factor for cardiometabolic mortality in China.[9]

Previous studies have assessed the relationship between fruit and vegetable intake with incident hypertension and BP, but the results were inconsistent.[10–15] The Dietary Approaches to Stop Hypertension (DASH) intervention study showed that a diet rich in fruit and vegetable could substantially reduce BP,[10] and some prospective studies also found a beneficial effect of fruit and vegetable on the prevention of hypertension.[11–13] However, no significant associations were found in the Women's Health Study (WHS) cohort[14] and the Seguimiento University of Navarra (SUN) cohort.[15] A recently published meta-analysis of the association between fruit and vegetable and hypertension indicated that the increasing consumption of fruit or TFV was associated with a reduced risk of hypertension, but there was no significant association between vegetable intake and hypertension.[16] Thus far, most studies on the relationship between the consumption of fruit and vegetable and hypertension were conducted in Western populations. Evidence from the Chinese population is limited.[13] Therefore, the relationship between fruit and vegetable intake and hypertension risk warrants further investigation in a large Chinese cohort.

This study aimed to systematically examine the association between fruit and vegetable intake and incident hypertension based on the project of Prediction for Atherosclerotic Cardiovascular Disease Risk in China (China-PAR).

2 | SUBJECTS AND METHODS

2.1 | Study population

All participants were from three cohorts with dietary records in the China-PAR project, including the China Multicenter Collaborative Study of Cardiovascular Epidemiology [China MUCA (1998)], the International Collaborative Study of Cardiovascular Disease in Asia (InterASIA), and the Community Intervention of Metabolic Syndrome in China and Chinese Family Health Study (CIMIC). A detailed description of these cohorts has been published elsewhere.[17] Briefly, the China MUCA (1998) and InterASIA were initiated in 1998 and 2000–2001, respectively. Three follow-up surveys were conducted during 2007–2008, 2012–2015, and 2018–2020. The CIMIC cohort in rural areas was established in 2007–2008 and conducted follow-up visits during 2012–2015 and 2018–2020. Unified protocols and similar questionnaires were used at the baseline and follow-up surveys in all three cohorts.

In total, 113,448 participants were enrolled at baseline in the three cohorts, 109,156 (96.2%) of whom were followed up successfully, while 4292 participants were lost to follow-up. Participants with missing BP information ($n = 49$), hypertension ($n = 37{,}977$), or cardiovascular diseases at baseline ($n = 567$), missing information on fruit and vegetable intake at baseline ($n = 777$), or missing BP information during the follow-up period ($n = 10{,}805$) were excluded from the current study, leaving 58,981 participants for the final analysis (Supporting Information: Figure S1).

2.2 | Data collection

Data on demographic characteristics, medical history, family history, and lifestyle risk factors, such as age, sex, ethnicity, education level, cigarette smoking, alcohol drinking, physical activity, and dietary habits (legumes, red meat, fish, fruit, vegetable, etc.), were obtained using a standard questionnaire, followed by a detailed physical examination with overnight fasting blood specimen collection.

Fruit and vegetable intake was assessed by trained research staff through face-to-face interviews using simplified food-frequency questionnaires (FFQs). Participants reported the frequencies and amounts of fruit and vegetable intake during the past year. The intake of fruit and vegetable was converted into an estimate of the daily intake of fruit and vegetable. The dietary intake of legumes, red meat, and fish was recorded in the same way as for fruit and vegetable.

Smokers were defined as individuals who smoked at least one cigarette/day for at least one year or reported smoking at least 400 cigarettes or 500 g of tobacco leaves throughout their lifetime. Smoking status was categorized as never, former, or current smoker. Current drinkers were defined as those who drank alcohol at least once a week during the past year. Physical activity was calculated as the average duration spent on various activities in the past year and was expressed as metabolic equivalent-h/day (MET-h/day). Body height and weight were measured twice using standard methods, and body mass index (BMI) was calculated as body weight (kg) divided by the square of body height (m^2). Trained research staff measured BP following the protocol recommended by the American Heart Association.[18] Before the BP measurement, participants were asked to avoid cigarette smoking, alcohol, coffee, or tea and exercise for at least 30 min. We provided four cuff sizes (small adult, adult, large adult, and thigh) to fit the participants' right arm.[18] Three BP measurements were taken in a seated position at 30 s intervals after at least 5 min of quiet rest. The average of the three measurements was used in the analysis. Diabetes was defined as participants with fasting blood glucose ≥7.0 mmol/L, use of hypoglycemic medications, or reporting diagnosed diabetes. Hypercholesterolemia was defined as total cholesterol ≥6.2 mmol/L.[19]

2.3 | Definition of hypertension

Within this study, hypertension was defined as systolic BP (SBP) ≥ 140 mmHg and/or diastolic BP (DBP) ≥ 90 mmHg and/or using antihypertensive medication within 2 weeks. High-normal BP was defined as SBP 120–139 mmHg and/or DBP 80–89 mmHg without taking antihypertensive medication according to the 2018 Chinese Guidelines for the Management of Hypertension.[3]

The date of onset of hypertension was ascertained based on the initial use of antihypertensive medication or the date of BP assessment during the interviews. If two dates were obtained, the earlier date was adopted.

2.4 | Statistical analysis

Baseline characteristics are presented as means ± standard deviations (SDs) for continuous variables with normal distribution and P_{50} (P_{25}, P_{75}) for those without normal distribution. Categorical variables are presented as numbers and percentages.

In the current study, person-years of follow-up were calculated from the date of the baseline survey examination to the date of the incident hypertension, death, or last follow-up, whichever occurred first. Multivariate-adjusted hazard ratios (HRs) and 95% confidence intervals (CIs) were calculated to estimate the association of TFV intake and fruit and vegetable intake with incident hypertension using Cox proportional hazards models. Considering the potential influence of the estimated effects in different cohort sources, a cohort-stratified Cox regression model was used. Participants were classified into five groups according to the quintiles of TFV (<250.0, 250.0–392.8, 392.9–516.6, 516.7–664.2, ≥664.3 g/day), fruit intake (<16.7, 16.7–35.6, 35.7–71.3, 71.4–149.9, ≥150.0 g/day), and vegetable intake (<200.0, 200.0–299.9, 300.0–449.9, 450.0–499.9, ≥500.0 g/day), respectively. To separate the confounding effects of covariates, three models were fitted: In model 1, we adjusted for age, sex (male or female), residence (urban or rural), region (north or south), and education level (less than high school or not); in model 2, we additionally adjusted for BMI, family history of hypertension (yes or no), red meat intake (≥75 g/day or not), legume intake (≥125 g/day or not), fish intake (≥200 g/week or not), smoking status (never, former, or current smoker), current drinker (yes or no), and physical activity (MET-h/day, quartiles) at baseline; in model 3, we further adjusted for diabetes (yes or no), hypercholesterolemia (yes or no,) and high-normal BP (yes or no) at baseline. When analyzed separately, fruit and vegetable were additionally adjusted for each other in model 2. Trend tests were conducted using the median of intakes of TFV, fruit, and vegetable in each quintile as continuous variables in models. Moreover, we divided participants into two groups according to the recommended intake level (500.0 g/day of TFV, 200.0 g/day of fruit, and 300.0 g/day of vegetable),[7] and further categorized participants under the recommended intake level into three subgroups according to TFV (<200.0, 200.0–349.9, 350.0–499.9 g/day), fruit (<50.0, 50.0–99.9, 100.0–199.9 g/day), and vegetable (<100.0, 100.0–199.9, 200.0–299.9 g/day), respectively. A restricted cubic spline with three knots (25th, 50th and 75th percentiles of intake) was adopted to assess the shape of the association between TFV, fruit and vegetable intake, and incident hypertension, adjusted for the same covariates as in model 3.

To investigate the potential effect modifications, subgroup analyses were performed according to baseline characteristics, including sex (male or female), age (≥60 years or not), education level (less than high school or not), smoker (yes or no), overweight/obesity (BMI ≥ 25.0 kg/m^2 or not), high-normal BP (yes or no), and diabetes (yes or no). We then performed a two-sample Z test to assess the statistical significance of the effect in subgroup analyses.[20] In addition, sensitivity analyses were conducted after excluding incident hypertension during the first 3 years of follow-up.

Data were analyzed using the SAS statistical package (version 9.4 SAS Institute, Inc.). All statistical tests were two-sided, with a $p < 0.05$ considered significant.

3 | RESULT

3.1 | Baseline characteristics

Among the 58,981 participants, the mean age at baseline was 48.5 years, and 38.6% were male. The P_{50} (P_{25}, P_{75}) of TFV, fruit, and vegetable intake at baseline was 471.4 (271.4, 607.1) g/day, 50.0 (17.9, 142.9) g/day, and 383.0 (250.0, 500.0) g/day, respectively. The characteristics of participants according to the quintiles of TFV intake are presented in Table 1. Participants with a higher TFV intake were inclined to be well-educated and had a lower proportion of family history of hypertension.

3.2 | Association of fruit and vegetable with incident hypertension

Over the course of 640,795 person-years of follow-up (a mean follow-up of 11.2 years), 21,008 incident hypertension cases were identified. An inverse association was observed between TFV, fruit, and vegetable intake, and the risk of incident hypertension. Compared with participants in the first quintile (Q1), the multivariate-adjusted HRs (95% CIs) were 0.90 (0.86–0.95), 0.85 (0.81–0.90), 0.82 (0.78–0.86), and 0.83 (0.78–0.88) for participants in quintiles 2–5 of TFV intake ($p_{trend} < 0.001$), respectively. For fruit, the corresponding HRs (95% CIs) were 0.91 (0.87–0.96), 0.86 (0.82–0.90), 0.81 (0.75–0.88), and 0.88 (0.84–0.92) ($p_{trend} < 0.001$), respectively. For vegetable, the corresponding HRs (95% CIs) were 0.92 (0.87–0.99), 0.85 (0.80–0.90), 0.84 (0.76–0.93), and 0.75 (0.71–0.80) ($p_{trend} < 0.001$), respectively (Table 2). Additionally, the results of the restricted cubic spline analysis were consistent with those of the categorical analyses (Figure 1). There was a nonlinear inverse association ($p_{nonlinear} < 0.001$) between TFV intake and incident hypertension, and this trend tended to be flattened when the intake was above approximately 500 g/day. We found similar nonlinear associations of fruit ($p_{nonlinear} < 0.001$) and vegetable ($p_{nonlinear} = 0.004$) intakes with the risk of new-onset hypertension.

3.3 | Association of underrecommended levels of intake with hypertension

In further analyses according to the recommended intake level, we found that increasing TFV intake, even though still insufficient (below the recommendation of 500.0 g/day) by the guideline, also protected against hypertension. Individuals whose TFV intake was above the recommended level (≥500.0 g/day) had a 17% lower risk (HR: 0.83, 95% CI: 0.79–0.87) of incident hypertension compared with those whose intake was less than 200.0 g/day. Individuals with TFV intakes of 200.0–349.9 g/day and 350.0–499.9 g/day, still below the recommended level but above 200 g/day, were associated with a lower risk of incident hypertension compared to those with less than 200.0 g/day, with HRs (95% CIs) of 0.96 (0.91–1.01) and 0.86 (0.81–0.92), respectively. Compared with those with fruit intake <50.0 g/day, participants with fruit intake meeting the recommended level (≥200.0 g/day) had a 10% (HR: 0.90, 95% CI: 0.86–0.94) lower risk of incident hypertension. We found that a vegetable intake above the recommended level (≥300.0 g/day) was associated with a 20% lower risk (HR: 0.80, 95% CI: 0.74–0.86) of incident hypertension when compared to very low intakes (less than 100.0 g/day). Fruit and vegetable intake below the recommended levels still had a significantly protective effect (Table 3).

TABLE 1 Baseline characteristics of participants according to intake of TFV.

Characteristics	All	Intake of TFV (g/day) Q1 (<250.0)	Q2 (250.0–399.9)	Q3 (400.0–516.6)	Q4 (516.7–664.2)	Q5 (≥664.3)
No. of participants	58,981	10,679	12,669	11,631	11,613	12,389
Fruit intake (g/day)	50.0 (17.9, 142.9)	21.4 (7.1, 35.7)	35.7 (14.3, 71.4)	71.4 (16.7, 150.0)	71.4 (35.7, 150.0)	200.0 (50.0, 234.0)
Vegetable intake (g/day)	383.0 (250.0, 500.0)	125.0 (100.0, 150.0)	250.0 (250.0, 300.0)	400.0 (300.0, 450.0)	500.0 (450.0, 50.0)	650.0 (600.0, 750.0)
Age (year)	48.5 ± 11.5	49.1 ± 12.4	48.9 ± 12.1	49.2 ± 11.6	48.7 ± 11.4	47.0 ± 9.9
Male, *n* (%)	22,743 (38.6)	3864 (36.2)	4676 (36.9)	4380 (37.7)	4292 (37.0)	5531 (44.6)
Urban resident, *n* (%)	5644 (9.6)	120 (1.1)	158 (1.3)	821 (7.1)	767 (6.6)	3778 (30.5)
Northern, *n* (%)	26,966 (45.7)	2166 (20.3)	5510 (43.5)	5728 (49.3)	7170 (61.7)	6392 (51.6)
High school education or above, *n* (%)	8925 (15.2)	1021 (9.6)	1351 (10.7)	1606 (13.8)	1673 (14.4)	3274 (26.6)
Family history of hypertension, *n* (%)	13,593 (23.1)	3036 (28.4)	3409 (26.9)	2537 (21.8)	2589 (22.3)	2022 (16.3)
Former smoker, *n* (%)	1880 (3.2)	299 (2.8)	380 (3.0)	335 (2.9)	271 (2.3)	595 (4.8)
Current smoker, *n* (%)	13,437 (22.9)	2359 (22.3)	2751 (21.8)	2513 (21.7)	2327 (20.1)	3487 (28.2)
Current drinker, *n* (%)	10,365 (17.6)	1712 (16.0)	1914 (15.1)	2062 (17.7)	1879 (16.2)	2798 (22.6)
Physical activity (MET-h/day)	37.6 ± 23.3	35.0 ± 20.7	39.4 ± 23.6	38.7 ± 23.6	40.0 ± 23.7	34.4 ± 23.8
Red meat intake ≥75 g/day, *n* (%)	8544 (14.5)	894 (8.4)	1049 (8.3)	1654 (14.2)	1208 (10.4)	3739 (30.2)
Legume intake ≥125 g/day, *n* (%)	2755 (4.7)	288 (2.7)	728 (5.8)	576 (5.0)	624 (5.4)	539 (4.4)
Fish intake ≥200 g/w, *n* (%)	21,458 (36.4)	3766 (35.3)	3990 (31.5)	4591 (39.5)	3742 (32.2)	5369 (43.3)
SBP (mmHg)	117.0 ± 11.4	117.1 ± 11.3	117.1 ± 11.4	117.4 ± 11.7	117.9 ± 11.3	115.6 ± 11.3
DBP (mmHg)	73.6 ± 8.0	72.9 ± 7.8	73.2 ± 8.0	73.5 ± 8.1	74.1 ± 7.9	74.1 ± 7.9
Total cholesterol (mmol/L)	4.4 ± 0.9	4.2 ± 0.8	4.3 ± 0.9	4.5 ± 0.9	4.4 ± 0.9	4.7 ± 0.9
Triglycerides (mmol/L)	1.2 (0.9, 1.7)	1.2 (0.9, 1.7)	1.3 (0.9, 1.8)	1.2 (0.9, 1.7)	1.2 (0.8, 1.7)	1.2 (0.9, 1.7)
HDL-C (mmol/L)	1.3 ± 0.3	1.3 ± 0.3	1.3 ± 0.3	1.4 ± 0.3	1.3 ± 0.3	1.3 ± 0.3
BMI (kg/m^2)	23.1 ± 3.3	22.6 ± 3.2	23.0 ± 3.3	23.3 ± 3.3	23.4 ± 3.3	23.2 ± 3.2
Diabetes, *n* (%)	2339 (4.2)	403 (4.0)	506 (4.3)	453 (4.3)	490 (4.5)	487 (4.1)
High-normal BP, *n* (%)	27,797 (47.1)	4811 (45.1)	5843 (46.1)	5639 (48.5)	5857 (50.4)	5647 (45.6)
Hypercholesterolemia, *n* (%)	1911 (3.4)	193 (1.9)	290 (2.4)	373 (3.4)	346 (3.2)	709 (5.9)

Note: Continuous variables with normal distribution are presented as mean ± standard deviation, and those without normal distribution are presented as P50 (P25, P75). Categorical variables are presented as number and percentage.

Abbreviations: BMI, body mass index; BP, blood pressure; DBP, diastolic blood pressure; HDL-C, high-density lipoprotein-cholesterol; SBP, systolic blood pressure; TFV, total fruit and vegetable.

3.4 | Subgroup and sensitivity analyses

Subgroup analyses of the TFV intake were conducted to examine the potential effects of the modifications (Supporting Information: Figure S2). The inverse associations between TFV intake and incident hypertension were consistent across subgroups, including sex, age, education level, high-normal BP, diabetes, overweight/obesity, and smoking, and no effect modification was observed for these subgroups. Similar results were also observed for fruit and vegetable intake (Supporting Information: Figure S3).

After excluding participants with incident hypertension in the first 3 years of follow-up, the results of the sensitivity analyses were not substantially different from the primary analyses. The significant inverse associations persisted between the intake of TFV, fruit, and vegetable, and the risk of hypertension (all $p_{\text{trend}} < 0.001$) (Supporting Information: Table S1).

TABLE 2 Hazard ratios of incident hypertension associated with fruit and vegetable intake.

Items	Q1	Q2	Q3	Q4	Q5	p_{trend}
TFV						
Range (g/day)	<250.0	250.0–392.8	392.9–516.6	516.7–664.2	≥664.3	—
No. cases/no. at risk (21,008/58,981)	3936/10,679	4128/12,669	4048/11,631	3751/11,613	5145/12,389	—
Incidence rate (per 1000 person-years)	36.8	31.7	31.9	30.6	33.4	—
HR (95% CI)						
Model 1	Ref.	0.91 (0.87–0.95)	0.86 (0.82–0.90)	0.84 (0.80–0.87)	0.87 (0.82–0.91)	<0.001
Model 2	Ref.	0.90 (0.86–0.94)	0.85 (0.81–0.89)	0.82 (0.78–0.86)	0.81 (0.76–0.85)	<0.001
Model 3	Ref.	0.90 (0.86–0.95)	0.85 (0.81–0.90)	0.82 (0.78–0.86)	0.83 (0.78–0.88)	<0.001
Fruit						
Range (g/day)	<16.7	16.7–35.6	35.7–71.3	71.4–149.9	≥150.0	—
No. cases/no. at risk (21,008/58,981)	4289/11,139	4160/11,081	3323/9584	4724/13,881	4512/13,296	—
Incidence rate (per 1000 person-years)	35.7	31.5	31.4	29.0	33.7	—
HR (95% CI)						
Model 1	Ref.	0.92 (0.88–0.97)	0.87 (0.83–0.91)	0.82 (0.76–0.88)	0.89 (0.85–0.93)	<0.001
Model 2[a]	Ref.	0.92 (0.87–0.96)	0.87 (0.83–0.92)	0.82 (0.76–0.88)	0.87 (0.83–0.90)	<0.001
Model 3[a]	Ref.	0.91 (0.87–0.96)	0.86 (0.82–0.90)	0.81 (0.75–0.88)	0.88 (0.84–0.92)	<0.001
Vegetable						
Range (g/day)	<200.0	200.0–299.9	300.0–449.9	450.0–499.9	≥500.0	—
No. cases/no. at risk (21,008/58,981)	3744/10,293	3742/12,011	4431/12,949	1339/3274	7752/20,454	—
Incidence rate (per 1000 person-years)	39.8	35.0	31.5	30.4	29.4	—
HR (95% CI)						
Model 1	Ref.	0.90 (0.84–0.96)	0.81 (0.76–0.86)	0.82 (0.75–0.89)	0.73 (0.69–0.77)	<0.001
Model 2[b]	Ref.	0.91 (0.85–0.97)	0.85 (0.80–0.90)	0.84 (0.77–0.93)	0.74 (0.70–0.78)	<0.001
Model 3[b]	Ref.	0.92 (0.87–0.99)	0.85 (0.80–0.90)	0.84 (0.76–0.93)	0.75 (0.71–0.80)	<0.001

Note: Model 1: adjusted for age (continuous), sex (male or female), residence (urban or rural), region (south or north), and education level (less than high school or not). Model 2: further adjusted for BMI (continuous), family history of hypertension (yes or no), legume consumption (≥125 g/day or not), red meat consumption (≥75 g/day or not), fish consumption (≥200 g/week or not), smoking status (current, former, never), current drinker (yes or no), and physical activity (quartiles). Model 3: further adjusted for diabetes (yes or no), hypercholesterolemia (yes or no), and high-normal BP (yes or no).

Abbreviations: BMI, body mass index; BP, blood pressure; CI, confidence interval; HR, hazard ratio; TFV, total fruit and vegetable.

[a]Models additionally adjusted the intake of vegetable.

[b]Models additionally adjusted the intake of fruit.

4 | DISCUSSION

Based on the large prospective cohorts among the Chinese population, the current study indicates that an inverse and nonlinear dose–response relationship exists between TFV intake and the risk of hypertension and also that increasing TFV intake has a protective effect on incident hypertension even if the intake is below the recommended level.[7] These findings provide strong evidence to support that a high fruit and vegetable intake plays an important role in preventing hypertension.

Several cohort studies have previously assessed the association of fruit and vegetable intake with BP and the risk of hypertension.[11–15,21–26] Consistent results in Portuguese[21] and United States[11] adult cohorts revealed that higher TFV intake was significantly associated with a reduced risk of incident hypertension. A previous study in China, including 5659 participants and 866 new cases of hypertension, found an inverse association between TFV intake and the incidence of hypertension, although the sample size was relatively small.[13] In line with these results, our study found that a long-term higher TFV intake was associated with a lower risk of incident hypertension. Recently, results from the same cohorts indicated that an increased TFV intake was associated with a decreased risk of stroke, cardiovascular disease

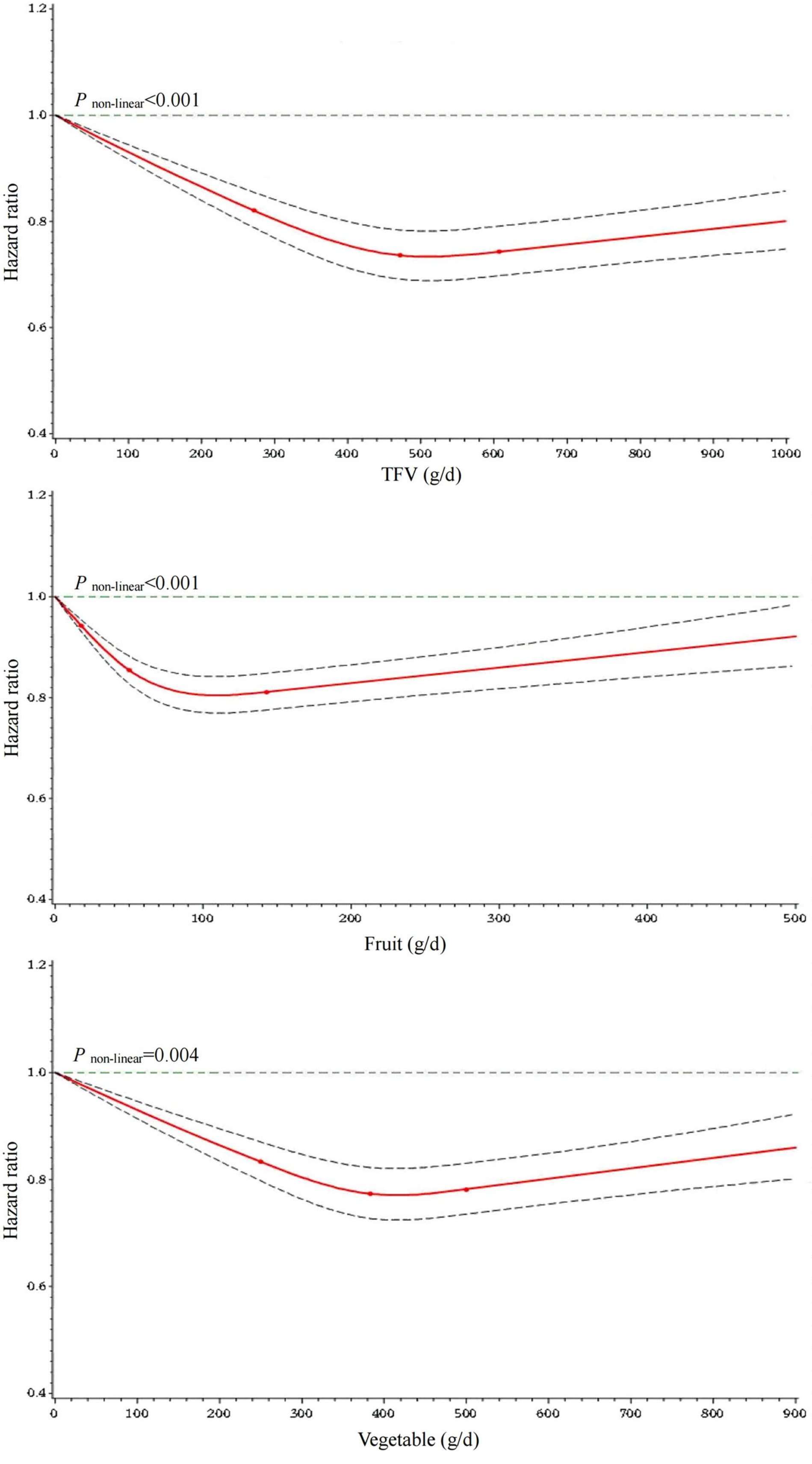

FIGURE 1 (See caption on next page)

TABLE 3 Hazard ratios of incident hypertension associated with lower intake of fruit and vegetable

	Not meeting recommended consumption			Meeting recommended consumption
	Group 1	Group 2	Group 3	
TFV				
Range (g/day)	<200.0	200.0–349.9	350.0–499.9	≥500.0
No. cases/no. at risk (10,515/30,440)	2992/7945	4325/13,070	3198/9425	10,493/28,541
Incidence rate (per 1000 person-years)	37.7	32.8	31.0	32.2
HR (95% CI)				
Model 1	Ref.	0.97 (0.92–1.02)	0.89 (0.84–0.94)	0.85 (0.81–0.88)
Model 2	Ref.	0.96 (0.91–1.00)	0.87 (0.83–0.92)	0.82 (0.78–0.86)
Model 3	Ref.	0.96 (0.91–1.01)	0.86 (0.81–0.92)	0.83 (0.79–0.87)
Fruit				
Range (g/day)	<50.0	50.0–99.9	100.0–199.9	≥200.0
No. cases/no. at risk (17,092/47,967)	9909/26,824	3637/10,857	3546/10,286	3916/11,014
Incidence rate (per 1000 person-years)	36.3	30.5	29.9	30.0
HR (95% CI)				
Model 1	Ref.	0.89 (0.85–0.92)	0.89 (0.85–0.92)	0.90 (0.86–0.94)
Model 2[a]	Ref.	0.89 (0.85–0.93)	0.88 (0.84–0.91)	0.88 (0.84–0.92)
Model 3[a]	Ref.	0.88 (0.84–0.92)	0.87 (0.83–0.91)	0.90 (0.86–0.94)
Vegetable				
Range (g/day)	<100.0	100.0–199.9	200.0–299.9	≥300.0
No. cases/no. at risk (7486/22,304)	912/2350	2832/7943	3742/12,011	13,522/36,677
Incidence rate (per 1000 person-years)	39.3	34.7	31.5	32.4
HR (95% CI)				
Model 1	Ref.	0.96 (0.89–1.03)	0.93 (0.87–1.00)	0.83 (0.77–0.89)
Model 2[b]	Ref.	0.94 (0.87–1.02)	0.91 (0.84–0.98)	0.82 (0.76–0.88)
Model 3[b]	Ref.	0.91 (0.84–0.99)	0.87 (0.80–0.94)	0.80 (0.74–0.86)

Note: Model 1: adjusted for age (continuous), sex (male or female), residence (urban or rural), region (south or north), and education level (less than high school or not). Model 2: further adjusted for BMI (continuous), family history of hypertension (yes or no), legume consumption (≥125 g/day or not), red meat consumption (≥75 g/day or not), fish consumption (≥200 g/week or not), smoking status (current, former, never), current drinker (yes or no), and physical activity (quartiles). Model 3: further adjusted for diabetes (yes or no), hypercholesterolemia (yes or no), and high-normal BP (yes or no).

Abbreviations: BMI, body mass index; BP, blood pressure; CI, confidence interval; HR, hazard ratio; TFV, total fruit and vegetable.

[a]Models additionally adjusted the intake of vegetable.

[b]Models additionally adjusted the intake of fruit.

(CVD), and all-cause mortality.[27,28] These results are strongly supported by our findings that the incidence of hypertension, an important risk factor for incident CVD, decreased with increasing TFV intake.

When fruit and vegetable were considered individually, their association with hypertension remained controversial. A Chinese cross-sectional study among adolescents (13–17 years old) indicated that participants

FIGURE 1 Restricted cubic spline curves of the association between TFV consumption and risk of incident hypertension. Adjusted for age (continuous), sex (male or female), residence (urban or rural), region (south or north), education level (less than high school or not), BMI (continuous), family history of hypertension (yes or no), legume consumption (≥125 g/day or not), red meat consumption (≥75 g/day or not), fish consumption (≥200 g/week or not), smoking status (current, former, never), current drinker (yes or no), cohort sources, physical activity (quartiles) diabetes (yes or no), hypercholesterolemia (yes or no), and high-normal BP (yes or no). With the exception of TFV intake, models also mutually adjusted for fruit intake and vegetable intake. Solid lines represented point estimates of the hazard ratios and dashed lines represented 95% confidence intervals. BMI, body mass index; TFV, total fruit and vegetable.

with vegetable intake ≥3 servings/day (1 serving is nearly equal to 200 g) had a 26% lower risk of high BP compared to those with vegetable intake <1 serving/day.[29] Sufficient vegetable consumption (at least 12 servings/week) was also proved to be associated with a reduced risk of hypertension in indigenous Africans.[30] Two prospective studies from Japan and Korea both found that only high fruit intake, rather than vegetable, was associated with a lower risk of incident hypertension.[25,26] However, our results showed that the significant association of both fruit and vegetable consumption with the risk of hypertension was clear in our population. We speculate that differences in cooking and dietary patterns may have led to these inconsistencies in results. Additionally, either fruit or vegetable are consumed just as part of the whole diet, and other foods obtained from the diet might confound the present results, thus affecting the real effect of fruit or vegetable. The relationship between fruit or vegetable and the risk of hypertension individually needs to be explored in future studies.

Additionally, some randomized controlled trials[31] and cohort studies[12,32] have found that higher fruit and vegetable intake was significantly associated with lower BP levels. A meta-analysis including 17 randomized controlled trials indicated diet patterns, such as DASH, Mediterranean diet, and so on, that are rich in fruit and vegetable could reduce SBP and DBP by 4.26 mmHg (95% CI: 3.34–5.18 mmHg) and 2.38 mmHg (95% CI: 1.87–2.89 mmHg), respectively.[31] The Chicago Western Electric Study found increasing fruit and vegetable intake could delay the progression of elevated BP. In comparison with participants in lower intake groups, the changes of SBP in the groups with higher fruit and vegetable were decreased by 2.2 mmHg ($p < 0.05$) and 2.8 mmHg ($p < 0.01$), respectively, during the 7 years of follow-up.[12] A similar conclusion was also proven in a cohort study from France.[32]

Various dietary guidelines have advocated high fruit and vegetable intake as an important component of a healthy diet and provided an exact value of recommended intake.[7,33] However, 78.0% of adults from mainly low- and middle-income countries consumed less than the level of five daily servings (400 g/day) of fruit and vegetable.[34] According to a survey from 1991 to 2011 in China, the proportion of people who consumed fruit (17.4%) and vegetable (50.2%) meeting the recommended intake is still small, and the intake of vegetable shows a downward trend.[35] Most of the previous evidence only emphasized that adequate intake of fruit and vegetable could lead to a lower risk of hypertension,[16] CVD, and mortality[36] than individuals with very low intake of fruit and vegetable, and the intake of fruit and vegetable combined associated with health benefits was up to 800 g/day.[16] Our findings highlighted the benefits of making small increases in the consumption of fruit and vegetable even if it was still below the recommended guideline level.

The mechanisms by which fruit and vegetable are associated with hypertension are not fully understood. Many known nutrients are rich in fruit and vegetable, such as dietary fiber, potassium, magnesium, flavonoid, and vitamin C. First, potassium and magnesium can regulate BP through vasodilation, enhanced urine flow, reduced renal renin release, and negative sodium (Na^+) balance.[4,37,38] Second, vitamin C, flavonoids, and other antioxidants contained in fruit and vegetable can reduce oxidative stress and inflammatory responses, improve vascular endothelial function, and help maintain BP homeostasis.[5,39] In addition, the gut microbiota can be modulated by dietary fiber from fruit and vegetable, leading to a lower BP.[40]

The major strengths of this study are that it included a large number of participants, a population-based prospective design, a high follow-up rate (92.79%), and stringent quality control procedures, which guaranteed the credibility of our conclusions. However, this study had a few limitations. First, the total energy intake or exact food type cannot be acquired from existing data; thus, it is difficult to assess the different effects of the varieties of fruit and vegetable. Second, a high-salt diet had significant effects on BP levels, while information on dietary sodium intake was not collected in our study, preventing us from taking salt intake into consideration. Finally, self-reporting of dietary intake by questionnaire in our cohort was a crude method and constituted a well-known weakness due to possible recall bias, which meant that there might exist a considerable risk of misclassifying the amount of fruit and vegetable consumed. Further validation of the dietary assessments will be conducted in our future studies.

In conclusion, higher fruit and vegetable intake was inversely associated with the risk of hypertension among Chinese adults. Our findings supported the idea that increasing fruit and vegetable intake has significant public health implications in preventing hypertension.

AUTHOR CONTRIBUTIONS

Zhi He: Methodology, formal analysis, visualization, writing—original draft. Yanhui Jia: Formal analysis, visualization, writing—review and editing. Jianxin Li: Investigation, data curation, methodology, writing—review and editing. Jie Cao: Investigation, data curation. Fangchao Liu: Funding acquisition, methodology, writing—review and editing. Hongfan Li: Investigation. Jichun Chen: Investigation. Dongsheng Hu: Investigation. Chong Shen: Investigation. Yingxin Zhao: Investigation. Xiaoqing Liu: Investigation. Ling Yu: Investigation. Jianfeng Huang: Methodology, writing—review and editing. Xiangfeng Lu: Resources, project administration, supervision, funding acquisition, writing—review and editing. Dongfeng Gu: Resources, project administration, supervision, funding acquisition, writing—review and editing. Shufeng Chen: Conceptualization, project administration, methodology, supervision, funding acquisition, writing—review and editing.

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CONFLICTS OF INTEREST STATEMENT

Professor Xiangfeng Lu and Dongfeng Gu are members of the Chronic Diseases and Translational Medicine editorial board and are not involved in the peer review process of this article. The remaining authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The authors do not have permission to share data.

ETHIC STATEMENTS

The China-PAR project was approved by the Institutional Review Board at Fuwai Hospital in Beijing (Approval No: 2012-399). Informed consent was obtained from all study participants before data collection.

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SUPPORTING INFORMATION

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

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