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The association of fruit and vegetable consumption with changes in weight and body mass index in Chinese adults

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Title: The association of fruit and vegetables consumption with changes in weight and body mass index in Chinese adults: a cohort study

Article Type: Original Research

Keywords: adult; fruit and vegetables; weight; BMI.

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Abstract: Objectives: Findings regarding the benefits of fruit and vegetables (FV) on weight control are inconsistent and little is known among Chinese populations. Therefore, we examined the relationship between change in FV consumption, weight and change in body mass index (BMI) among Chinese adults, participants of the China Health and Nutrition Survey (CNHS).

Study design: A prospective cohort study.

Methods: Two waves of CNHS conducted in 2006 and 2011 were used. Continuous FV consumption increase was considered as the exposure and changes in weight and BMI as outcomes. Change in FV consumption was categorized into quintiles. Analysis of covariance and multiple linear regression models, after controlling for potential confounders such as energy intake, physical activity, and smoking, were used to describe the relationship between change in FV consumption and change in weight and BMI.

Results: A total of 4357 participants aged 18-65 years were included in this study. The respective weight and BMI gains in male individuals were 1.81 kg and 0.73 kg/m² in the fifth quintile of FV change relative to individuals in the first quintile (3.67 kg for weight gain and 1.48 kg/m² for BMI gain). An increase in FV consumption by 100 grams was associated with a 211 g weight loss (B= -2.11; 95% CI, -3.34, -0.89, p<0.001) and a decrease in BMI by 0.94 kg/m² (B=-0.94; 95% CI, -1.36, -0.46, p<0.001) in men; and a 140 g weight loss (B=-0.14; 95% CI, -0.97, 0.69, p=0.74) and a decrease in BMI by 0.29 kg/m² BMI (B=-0.29; 95% CI, -0.63, 0.06, p=0.11) in women.

Conclusions: Increase in FV consumption was associated with statistically significant weight loss and decrease in BMI among Chinese men, and, although suggested, weight loss among women was not significant. Considering the protective effect of FV on human health, increasing FV consumption in Chinese population is recommended.

Dear Sir or Madam,

I would like to submit the following manuscript for possible evaluation.

Manuscript (Original research) Title: **The association of fruit and vegetables consumption with changes in weight and body mass index in Chinese adults: a cohort study**

The prevalence of overweight and obesity has increased substantially in the past few decades worldwide. Obesity is a multi-factorial, complex condition, and no single intervention will be sufficient to prevent it. Multiple strategies are needed and one of such identified strategies includes increase in fruit and vegetables (FV) consumption. However, findings regarding the benefits of FV on weight control were inconsistent.

We assessed the relationship of FV intake with changes in body weight and BMI over a 4.6-year period in a large Chinese adult cohort. A total of 4357 participants aged 18-65 years were included in this study. The respective weight and BMI changes in male individuals were 1.81 kg and 0.73 kg/m² in the top quintile of FV change relative to individuals in the bottom quintile (3.67 kg for weight change and 1.48 kg/m² for BMI change). Increased one kilogram FV consumption was associated with a 2.11 kg weight loss (95% CI, -3.34, -0.89, p<0.001) and a 0.94 kg/m² BMI loss (95% CI, -1.36, -0.46, p<0.001) in men and a 0.14 kg weight loss (95% CI, -0.97, 0.69, p=0.74) and a 0.29 kg/m² BMI loss (95% CI, -0.63, 0.06, p=0.11) in women.

In conclusion, there was an inverse relationship of FV consumption with weight and BMI change among Chinese men. Protective effect of FV intake was also noted among women though not statistically significant. Considering the protective effect of FV consumption in human health and disease prevention, increasing FV consumption in Chinese population should be recommended.

I affirm that the manuscript is original research, and has been prepared in accordance with your Instructions to authors. **The authors have no conflicts of interest.** I also confirm that I full access to all aspects of the research and writing process, and takes final responsibility for the paper.

I have read the manuscript and I hereby affirm that the manuscript has been submitted solely to **Public Health**. The content of this manuscript or a major portion thereof has not been published previously, either in whole or in part, nor have the findings been posted online, and it is not being submitted for publication elsewhere, and each author has seen and approved the consents of the submitted manuscript.

Thanks very much for your attention to our paper.

Sincerely yours,

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Dear editors,

Thank you very much for your letter and the comments about our paper submitted to Public Health.

We have revised the manuscript following your comments. We hope these revisions will address your concerns.

Your acknowledgement will be highly appreciated.

Sincerely,

Qi-qiang He
Wuhan University
P.R.CHINA

**The association of fruit and vegetables consumption with changes in weight and
body mass index in Chinese adults: a cohort study**

Yuan S.^{1,*}, Yu H.J.^{1,*}, Liu M.W.¹, Huang Y.¹, Yang X.H.², Tang B.W.¹, Song Y.¹, Cao
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Running Head: Fruit, vegetables and body weight

*: These authors contributed equally to this work.

1 **Abstract**

2 Objectives: Findings regarding the benefits of fruit and vegetables (FV) on weight
3 control ~~were~~ are inconsistent and little ~~was~~ is known among Chinese populations.
4 Therefore, we examined the relationship between change in FV consumption, ~~and~~
5 weight and change in body mass index (BMI) ~~change~~ among Chinese adults,
6 participants of the China Health and Nutrition Survey (CNHS).

7 Study design: A prospective cohort study.

8 Methods: Two waves of CNHS China Health and Nutrition Survey (CNHS)
9 conducted in 2006 and 2011 were used. Continuous FV consumption increase was
10 considered as the exposure and changes in weight and BMI ~~changes~~ as outcomes.
11 Change ~~of~~ in FV consumption was categorized into quintiles. Analysis of covariance
12 and multiple linear regression models, after controlling for several potential
13 confounders such as energy intake, physical activity, and smoking, ~~etc.~~, were
14 employed ~~used~~ to investigate ~~describe~~ the relationship between change in FV
15 consumption and change in weight and BMI ~~change~~.

16 Results: A total of 4357 participants aged 18-65 years were included in this study. The
17 respective weight and BMI gains in male individuals were 1.81 kg and 0.73 kg/m² in
18 the fifth quintile ~~5~~ of FV change relative to individuals in the first quintile ~~1~~ (3.67 kg
19 for weight gain and 1.48 kg/m² for BMI gain). An increase in ~~in~~ FV consumption by
20 100 grams ~~FV consumption~~ was associated with a 211 g weight loss (B=-2.11; 95%
21 CI, -3.34,-0.89, p<0.001) and a decrease in BMI by 0.94 kg/m² ~~BMI loss~~ (B=-0.94;
22 95% CI, -1.36,-0.46, p<0.001) in men; and a 140 ~~kg~~ weight loss (B=-0.14; 95% CI,
23 -0.97, 0.69, p=0.74) and a decrease in BMI by 0.29 kg/m² ~~BMI loss~~ (B=-0.29; 95% CI,
24 -0.63, 0.06, p=0.11) in women.

25 Conclusions: Increase in ~~An inverse association between~~ FV consumption was
26 associated with statistically significant ~~and~~ weight loss and decrease in BMI gain ~~was~~
27 found among Chinese men, and, although suggested, weight loss among women, was
28 not significant. Considering the protective effect of FV on human health, increasing
29 FV consumption in Chinese population ~~should be~~ is recommended.

1 Keywords: Adult; fruit and vegetables; weight; BMI.

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1 Introduction

2 The prevalence of overweight and obesity has increased substantially in the past
3 few decades worldwide^{1,2}. It was estimated that the proportion of overweight adults
4 increased from 28.8% in 1980 to 36.9% in 2013, which exacted a ~~huge-substantial~~
5 burden on people's health globally³. Obesity has been linked to an increased risk for
6 cardiovascular diseases (CVD), diabetes, some types of cancers, and osteoarthritis⁴.
7 Considering the challenges in treating obesity and achieving weight maintenance,
8 there is an urgent need for obesity prevention approaches across populations.

9 Obesity is a multi-factorial, complex condition, and no single intervention will
10 be sufficient to prevent it. Multiple strategies are needed and one of such identified
11 strategies includes an increase in fruit and vegetables (FV) consumption⁵. It has been
12 observed that increased FV consumption may reduce the risk of CVD, diabetes, and
13 certain cancers⁶. However, findings regarding the benefits of FV on weight control
14 were inconsistent. While some studies reported that increased FV consumption
15 reduced weight or body mass index (BMI)⁷⁻⁹, others noted no such relationship^{10,11}.

16 With rapid economic growth and industrialization¹², a dramatic rise in the
17 prevalence of overweight and obesity was observed among Chinese adults posing a
18 major threat to their health¹³. Simultaneously, ~~there was data suggest~~ a reduction of
19 vegetable consumption among this population. According to a recent study in China,
20 vegetable consumption of Chinese citizens decreased from 363.4 g/day in 1993 to
21 321.6 g/day in 2011, whereas it was reported that Chinese people ate only 90.1g fruit
22 daily in 2011¹⁴. Although some cross-sectional studies have explored the effects of
23 dietary pattern on obesity among Chinese adults^{15,16}, the longitudinal association
24 between FV consumption and obesity has not been investigated. Therefore, we
25 assessed the relationship of the change in FV intake with changes in body weight and
26 BMI over a 4.6-year period in a large cohort of Chinese adult ~~cohort~~.

28 Methods

29 *Study design and participants*

30 The China Health and Nutrition Survey (CHNS) is an ongoing prospective

1 cohort study [with data](#) from 1989 to 2011 [available for public use](#). The CHNS was
2 designed to provide representation of rural, urban, and suburban areas varying
3 substantially in geography, economic development, public resources, and health
4 indicators. A multistage random-cluster sampling method was employed to recruit
5 subjects. The original survey sites included eight provinces: Liaoning, Jiangsu,
6 Shandong, Henan, Hubei, Hunan, Guangxi, and Guizhou; a 9th province, Heilongjiang,
7 was added in 1997. Counties in the nine provinces were stratified by income (low,
8 middle, and high) and a weighted sampling scheme was used to randomly select four
9 counties in each province. Two cities (the provincial capital and a lower income city)
10 and four economically striated counties were selected in each province. Within cities,
11 two urban and two suburban communities were selected; and within counties, one
12 community in the capital city and three rural villages were chosen. Details of the
13 study design and recruitment methods have been described elsewhere¹⁷. The present
14 study was based on 2006 [wave](#) and 2011 [waves](#) of the CHNS. Written informed
15 consent was provided by each participant. The study protocol for this study was
16 approved by institutional review boards of University of North Carolina at Chapel
17 Hill, and National Institute for Nutrition and Health, Chinese Center for Disease
18 Control and Prevention.

19 *Outcomes*

20 The outcomes of the study include changes in weight and BMI between years
21 2006 and 2011. Participants' height and weight at baseline and follow-up were
22 measured by trained technicians using standard methods. Weight was measured with
23 participants in light clothing to [the nearest](#) 0.1 kg. Individual's height was measured to
24 [the nearest](#) 0.1 cm with participants being barefoot. BMI was defined as body weight
25 in kilograms divided by the square of height in meters.

26 *Exposure*

27 The exposure was defined as change in FV consumption (g/day) between years
28 2006 and 2011. FV consumption was assessed by three consecutive 24-hour dietary
29 recalls, which included two week days and one weekend day¹⁸. Individuals were
30 asked about the exact type and weight of food they consumed by trained interviewers

1 including food consumed away from home. A food system was specifically developed
2 for CHNS and Chinese Food Composition Tables, which included 162 fruit items and
3 256 vegetable items¹⁹. The average daily FV intake was derived from participant
4 responses.

5 *Confounders*

6 Information on gender, age, education, province, and lifestyle were collected
7 from self-administered questionnaires. Education level was defined as the highest
8 education the participants received. Lifestyle measures included physical activity (PA),
9 energy intake (EI), smoking status, alcohol and soft drink consumption. PA level was
10 calculated by multiplying the weekly time spent in each activity by metabolic
11 equivalent (MET) score, an indicator of average intensity of each PA²⁰. In this study,
12 we defined PA as the leisure PA domain according to the SLOTH model²¹, containing
13 13 items of active and sedentary leisure. ~~Energy intake (EI)~~ was measured by
14 aggregating the energy contained in each food daily consumed based on Chinese Food
15 Composition Tables. The information of smoking status, alcohol and soft drink
16 consumption were collected through a self-reported questionnaire. Current smoking
17 was assessed by two questions. Participants were first asked to report whether they
18 ever smoked. If yes, they were asked ~~by a following question that~~ if they still smoked.
19 ~~Respondents—Individuals~~ who reported ever smoking and still smoked were
20 considered as “current smoking”. Alcohol consumption was assessed by the question
21 “Did you ever drink alcohol (beer, white wine or other spirits) in the last year?” If yes,
22 they were defined as “current alcohol consumption”. Soft beverage consumption was
23 first assessed by the question “Did you consume soft drinks or sweetened beverage in
24 the last year?” If yes, participants were asked to report the frequency of soft drinks
25 and sweetened beverage. The response options included “daily”, “3-4 times per week”,
26 “1-2 times per week”, “1-3 times per month”, “less than one times per month”, and
27 “unknown”. Those who reported consuming soft drinks and sweetened beverages for
28 more than 3 times per week were classified as soft drink consumption. We used the
29 mean values of two waves to represent EI and PA level in the entire period
30 (2006-2011), however, for smoking status, alcohol and soft drink consumption, we

1 used two waves' information to represent them.

2 *Statistical analysis*

3 Sex differences in baseline characteristics were examined using t-test and a
4 chi-square test for continuous and categorical variables, respectively. Change of FV
5 consumption was categorized into quintiles. The difference in weight and BMI change
6 across quintiles of FV was assessed by analysis of covariance (ANCOVA) with
7 adjustment for ~~e~~ovariatesconfounders. In addition, three multivariable linear
8 regression models were employed to determine the relationship between FV
9 consumption and changes in weight and BMI: Model 1, adjusted for age (years);
10 Model 2, adjusted for age and baseline BMI (kg/m²); and Model 3, additionally
11 adjusted for other confounding factors including province, education level, EI, PA,
12 smoking status, alcohol ~~consumption~~ and soft drink intakeconsumption. All statistical
13 analyses were performed by using the SPSS statistical package (version 13.0; SPSS
14 Inc., Chicago, IL, USA) stratified by sex group.

16 **Results**

17 Of the 4793 participants aged 18 to 65 years in 2006 who, and had complete data
18 on FV intake and anthropometric measurements in both surveys, 436 were excluded
19 because of pregnancy (n=31), type 2 diabetes (n=129), cancer (n=42), CVD (n=110),
20 and extreme EI (<500 kcal/day and/or >4000 kcal/day) (n=124)²². Finally, a total of
21 4357 participants were included in this study.

22 Baseline characteristics of participants are shown in Table 1. Mean age of men
23 (45.8 years) did not significantly differ from that of women (46.4 years). Compared to
24 men, women were more likely to report completing less than high school education.
25 EI, FV intake and weight were on average higher in men than in women. There was a
26 significant sex difference in smoking status and alcohol consumption whereby men,
27 compared to women, were more likely to report current smoking and alcohol
28 consumption. In contrast, women were more than men to report soft drink
29 consumption. No sex difference was observed for BMI and PA.

30 Sex-specific change in weight and BMI by FV change quintiles from 2006 to

1 2011 are displayed in Figure 1 ($Q1 \leq -0.2$, $Q2 \leq -0.05$, $Q3 \leq 0.667$, $Q4 \leq 0.2233$,
2 $Q5 > 0.2233$). There was an ~~an significantly~~ inverse relationship between ~~increases~~
3 ~~change~~ in FV consumption and weight and BMI change during the study period in
4 men. The weight and BMI changes in male individuals were 1.81 kg and 0.73 kg/m²
5 in the Q5 of FV change relative to individuals in the Q1 (3.67 kg for weight change
6 and 1.48 kg/m² for BMI change). Compared with those with the lowest FV change
7 quintile, women in the highest FV change quintile showed a lower average BMI gain,
8 ~~however the results did not meet even though~~ statistically ~~insignificant~~. ~~However,~~
9 ~~†~~This trend in weight gain was not ~~found~~ observed.

10 The results of multiple linear regression analysis of the relationship between
11 change in FV intake and change in weight and BMI in men and women are presented
12 in Table 2. In men, there was a negative association between change in FV
13 consumption and change in weight and BMI whereby for each 100 grams increase in
14 FV intake, individual's weight would decrease by 211 g ($B = -2.11$; 95% CI:
15 $-3.34, -0.89$) and BMI would decrease by 0.94 kg/m² ($B = -0.94$; 95% CI: $-1.36, -0.46$).
16 Although a similar relationship was observed in women, the results were not
17 statistically significant.

18 19 **Discussion**

20 In this prospective cohort study of 4357 Chinese men and women, an inverse
21 association was observed between change in FV and weight and BMI change in
22 Chinese men. The findings were independent of age, baseline BMI, education level,
23 province, EI, PA, smoking status, and alcohol and soft drink consumption. The
24 findings in women followed the same pattern of those of men, ~~although~~ however, the
25 results did not reach statistical significance.

26 Previous results regarding the association of FV consumption and body weight
27 and BMI ~~were~~ are inconsistent. A meta-analysis of human randomized controlled
28 trials concluded that there was no empirical evidence that increasing FV would have a
29 discernable effect on body weight²³. Another systematic review suggested that the
30 inverse relationship between FV consumption and adiposity among overweight adults

1 was weak²⁴. However, a recent meta-analysis showed that high intake of fruits was
2 inversely associated with weight change, although no significant changes were
3 observed for vegetable or combined FV consumption²⁵. Furthermore, our findings
4 lend support to several epidemiological studies that revealed an inverse association
5 between FV consumption and weight and BMI gain⁷⁻⁹. In a 14-year study of American
6 adults, Bertoia et al. reported that one daily serving increase in total fruits and total
7 vegetable consumption was associated with 0.53 lb and 0.25 lb body weight loss,
8 respectively⁷. Similarly, while studying a European population, Buijsse et al. observed
9 weight loss of 14 grams per year per each 100 grams increase in FV intake during a
10 6.5-year follow-up⁸. Results for the equivocal results may include the different types
11 of design, dietary assessments, and various covariates. Therefore, further high-quality
12 research with long duration follow-up is still needed to confirm our findings.

13 In the present study, we found sex-specific relationships between FV
14 consumption change and weight and BMI change among Chinese adults. The results
15 ~~were~~ are in line with several studies that reported a less significantly inverse
16 relationship between FV consumption and weight gain among women compared to
17 men¹⁰. A large Mediterranean population study reported that a significantly inverse
18 association between FV consumption and weight gain was observed only among
19 men²⁶. However, similar relationships, in direction and magnitude, for men and
20 women were found between dietary factors and weight change in three US cohorts²⁷.
21 Potential reasons for sex difference of the associations between FV consumption and
22 weight and BMI gain might be explained by less vegetables consumption in women
23 compared to men²⁸. Furthermore, different socioeconomic factors and hormone level
24 between genders could also influence weight gain²⁹.

25 There are several hypothetical mechanisms by which FV may be protective
26 against obesity risks. One potential explanation for weight reduction by FV
27 consumption may be a decrease in the total energy intake and a consequent
28 amelioration of energy disequilibrium. Furthermore, several components of FV, such
29 as fiber content, glycemic load (GL) and biologically active substances (e.g.
30 polyphenols), might also responsible for their anti-obesity effects. Most FVs are rich

1 in fiber and active constituents and have a low GL. Fibers in FV increase satiety,
2 reduce hunger feeling and energy intake and prevent weight gain³⁰⁻³². Additionally,
3 lower-GL of FV produces fewer and smaller postprandial glucose spikes that may
4 decrease subsequent hunger and reduce total energy intake³³. Also, low-GL or
5 low-glycemic-index (~~GI~~) diets may increase resting energy expenditure³⁴, promoting
6 weight maintenance according to a clinical trial evidence. Moreover, polyphenols may
7 influence insulin sensitivity³⁵, the gut microbiome³⁶, or the anabolic state of adipose
8 tissue, which could contribute to the weight control in the long term.

9 To the best of our knowledge, the present study was among the first to
10 investigate the longitudinal relationship of FV consumption with weight and BMI
11 change among Chinese adult population. Nevertheless, there are several limitations in
12 our study. First, FV intake assessment using 24-h dietary recall may yield
13 measurement error. Nevertheless, this would be random error and tend to
14 underestimate the relationship of FV intake with weight change. Second, MET hours
15 per week could not actually reflect the energy cost of PA in individuals. However, it is
16 useful for providing population-based PA estimates. Third, although several covariates
17 have been adjusted in our results, we could not exclude the possibility that the
18 observed association may have been affected by some residual confounding factors.
19 Last, we only included participants aged 18 to 65 years in 9 provinces, thus the results
20 may not be generalizable to all Chinese adults.

21 In conclusion, there was an inverse relationship of FV consumption with weight
22 and BMI change among Chinese men. Protective effect of FV intake was also ~~noted~~
23 observed among women though not statistically significant. Considering the
24 protective effect of FV consumption in human health and disease prevention,
25 increasing FV consumption in Chinese population should be recommended.

27 **Funding**

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29 Food Safety; the China Centre for Disease Control; the National Institutes of Health
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1 R01HD38700]; the Fogarty International Center of the National Institutes of Health;
2 the China-Japan Friendship Hospital; and the Chinese Ministry of Health.

3 4 **Competing interests**

5 None.

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27 **Figure and table legends**

28 Table 1. Baseline characteristics of 4357 Chinese men and women aged 18 to 65 years in China
29 Health and Nutrition Survey (CHNS).

30 Table 2. Results of multivariable linear regression of the association between FV intake change

1 and weight and BMI change among 4357 Chinese adults.

2 | [Figure- 1.](#) Sex-specific weight and BMI change according to FV intake change quintiles (Qs)

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Table 1. Baseline characteristics of 4357 Chinese men and women aged 18 to 65 years in China Health and Nutrition Survey (CHNS)

	Men (n=1970)	Women (n=2387)	P
Age (years)	45.8 ± 11.0	46.4 ± 10.0	0.082
Education level, n (%)			<0.001
Below high school	1346 (68.3)	1895 (79.4)	
High school	518 (26.3)	421 (17.6)	
Above high school	106 (5.4)	71 (3.0)	
BMI (kg/m ²)	23.1 ± 3.1	23.3 ± 3.3	0.070
Weight (kg)	64.8 ± 10.6	56.9 ± 9.0	<0.001
FV consumption (g/day)	413.6 ± 251.7	396.7 ± 259.7	0.030
Average three-day energy intake (kcal/day)	2406.4 ± 615.8	2071.8 ± 587.4	<0.001
Physical activity (MET-hr/wk)	277.2 ± 62.4	279.0 ± 70.3	0.178
Current smoking, n (%)	1266 (64.3)	80 (3.4)	<0.001
Alcohol consumption, n (%)	1245 (63.2)	207 (8.7)	<0.001
Soft drink consumption, n (%)	387 (19.6)	600 (25.1)	<0.001

BMI, body mass index; MET-hr/wk, metabolic equivalent of task (MET) hours per week; FV, fruit and vegetables; Continuous variables were expressed in Mean ± Standard Deviation; Categorical variables were presented as counts and percentages.

Table 2. Results of multivariable linear regression of the association between FV intake change and weight and BMI change among 4357 Chinese adults.

	Weight Change		BMI Change	
	β (95%CI)	P	β (95%CI)	P
Men				
Model 1	-1.94 (-3.17,-0.71)	0.002	-0.88 (-1.33,-0.42)	<0.001
Model 2	-2.01 (-3.24,-0.79)	<0.001	-0.91 (-1.29,-0.29)	<0.001
Model 3	-2.11 (-3.34,-0.89)	<0.001	-0.94 (-1.36,-0.46)	<0.001
Women				
Model 1	-0.05 (-0.88,0.79)	0.909	-0.24 (-0.59,0.11)	0.177
Model 2	-0.12 (-0.95,0.71)	0.779	-0.28 (-0.62,0.07)	0.116
Model 3	-0.14 (-0.97,0.69)	0.743	-0.29 (-0.63,0.06)	0.106

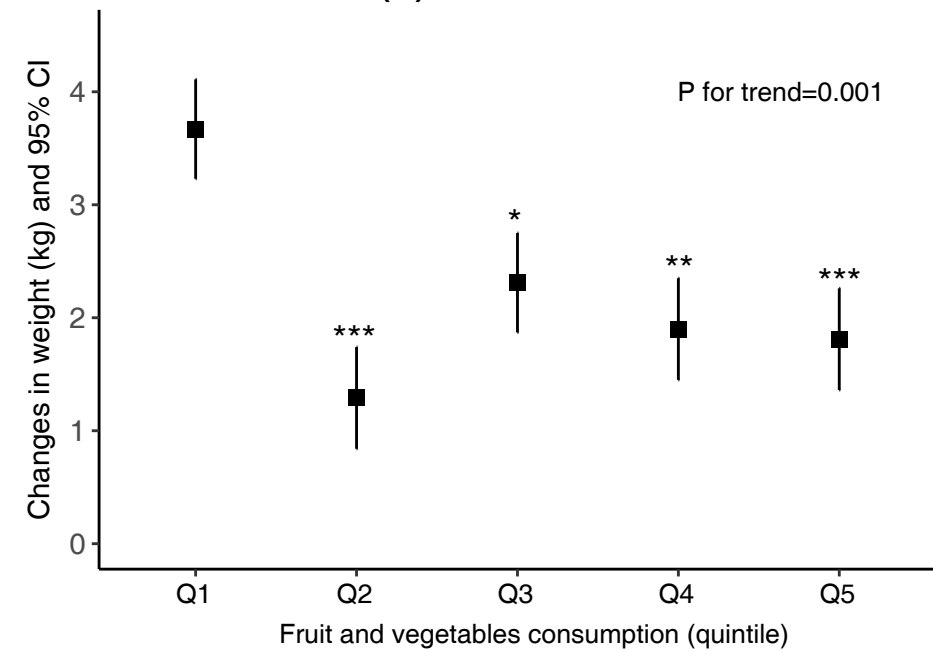
Notes: Model 1 adjusted for age;

Model 2 adjusted for age and baseline BMI;

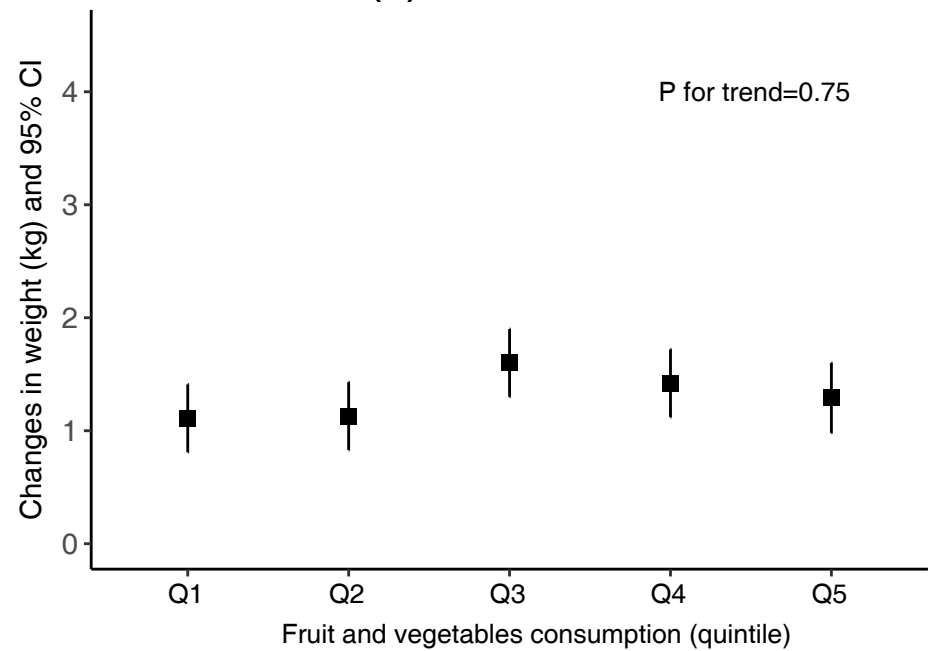
Model 3 adjusted for age, baseline BMI, province, education, three-day average energy intake, physical activity, smoking status, alcohol consumption and soft drink intake.

Figure(s)

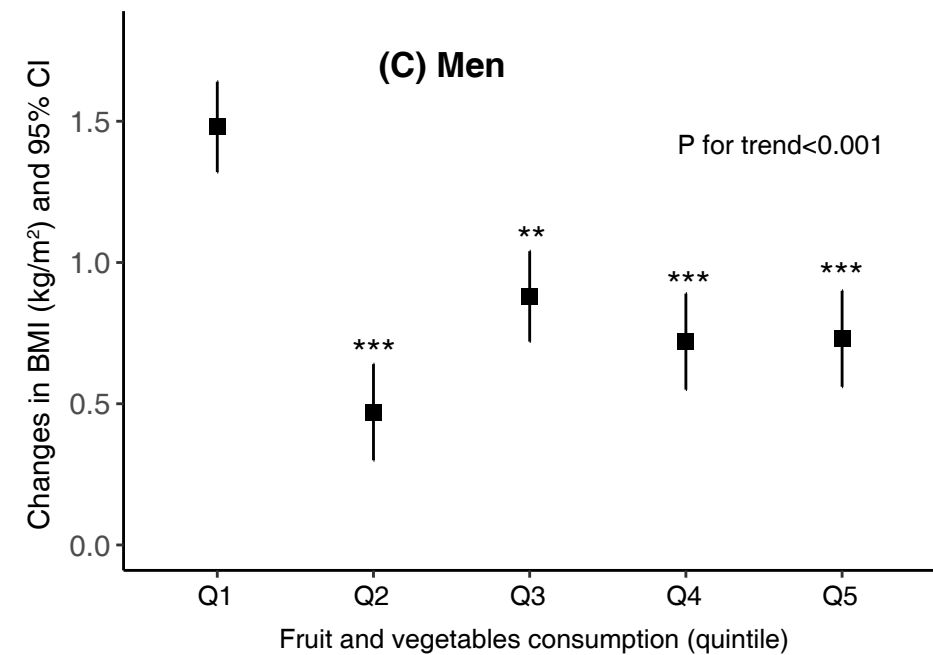
(A) Men



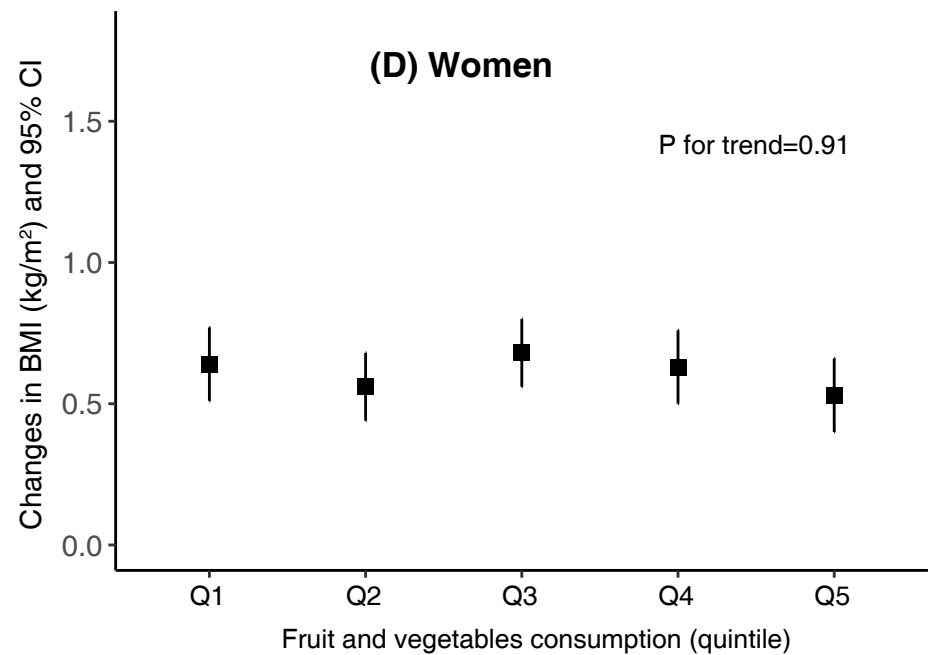
(B) Women



(C) Men



(D) Women



Highlights

- We examined **the association between** weight and BMI increase **and** fruit and vegetables intake in Chinese adults.
- Data collected from the China Health and Nutrition Survey **(2006 to 2011)** were analyzed.
- **Chinese men** with lower fruits and vegetable intake showed higher risks for weight and BMI gain compared with the counterparts with higher intake.