

Inverse relationship between coarse food grain intake and blood pressure among young Chinese adults

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Abstract

BACKGROUND: Coarse food grains are rich in dietary fiber and contain a wide range of nutrients with potential health benefits, such as blood pressure control. Coarse food grains are very popular in China, where hypertension is a major challenge. We evaluated the associations between coarse food grain consumption and blood pressure among young Chinese adults.

METHODS: A total of 104 men and women aged 18 to 35 years, who participated in a pilot study of the Carbohydrate Alternatives and Metabolic Phenotypes study, were included in the present analysis. Food frequency questionnaires were used to collect dietary intake data. Blood pressure was measured using a digital monitor. A multivariate general linear model was used to evaluate the putative associations.

RESULTS: Overall, 12.5 % of our participants have regular habits of coarse food grain intake (at least 4 days/Wk). Age was positively associated with both systolic blood pressure (SBP) and diastolic blood pressure (DBP) (all P for trend < 0.05). With multivariable adjustment, including for body mass index and physical activity level, the frequency of coarse food grain intake was inversely associated with both SBP and DBP (all P for trend < 0.05). Similar associations were observed for estimated daily coarse food grain intake with SBP (β coefficient \pm SE = -0.039 ± 0.017 , $P = 0.024$) and DBP (β coefficient \pm SE = -0.033 ± 0.013 , $P = 0.016$).

CONCLUSIONS: In our sample of young Chinese adults, higher coarse food grain intake was associated with lower SBP and DBP.

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Introduction

As an established risk factor for cardiovascular and kidney diseases, hypertension currently affects over 1 billion people worldwide ¹. It has also been estimated that elevated blood pressure currently kills 9 million people every year ¹. In China, over a quarter of adults aged 18 years or older were affected by hypertension in 2012 ². Growing evidence shows that dietary or lifestyle modifications are promising for blood pressure control. Such modifications include engaging in moderate physical activity, low alcohol and salt intake, and following dietary patterns high in consumption of fruit, vegetables, and low-fat dairy products^{3,4}. Higher consumption of whole grains has been associated with reduced blood pressure according to some observational ^{5,6} and experimental ⁷ studies, but not all ⁸. Many previous studies ⁵⁻⁷ were conducted in Europe or United States, where whole grains are typically consumed in the form of whole grain breads or breakfast cereals, whereas in Asian countries like China, whole grains are typically eaten in the form of brown rice ⁹. In fact, most of the rice consumed in China is white rice ¹⁰. However, another important grain source in traditional Chinese diets is coarse food grains, which are grains or various beans (usually mung, red, or kidney beans) other than rice and wheat products ¹¹. According to a report of the 2010–2012 Chinese Residents Nutrition and Health Surveillance, millet, corn, oats, adlay, and buckwheat were the most frequently

consumed coarse food grains¹². Coarse food grains are simply processed and are rich in fiber, B vitamins, and some trace minerals, which are similar to whole grains⁹. However, coarse food grain has a much lower price and greater availability than brown rice in China¹³. Those nutrient factors in these grains are believed to lead to beneficial effects on blood pressure control owing to the ability to improve insulin sensitivity and endothelial function⁵. The Dietary Guidelines for Chinese Residents (2016) recommend that 20% to 25% of consumed grains be in the form of coarse food grains, for optimum health benefits¹¹. However, to our knowledge, evidence is scarce regarding the associations of coarse food grain intake and blood pressure or other metabolic outcomes.

According to a nationwide sample of 0.5 million Chinese adults, systolic blood pressure (SBP) is approximately linearly associated with age whereas diastolic blood pressure (DBP) increases with age, up to age 55 years¹⁴. The vascular risk attributable to increased SBP is twice as high at ages 40–49 years as at ages 70–79 years¹⁴. It is noteworthy that young adults have an overall lower prevalence of hypertension, yet their rates of awareness and treatment of hypertension are markedly lower than older adults¹⁵. Unfortunately, most studies regarding the effectiveness of dietary modification and improvement in blood pressure have been conducted among middle-aged or older adults; thus, evidence in young individuals is lacking¹⁶.

In the present study, we report the associations between frequency and estimated daily intake of coarse food grains and blood pressure among young Chinese adults.

Methods

Study population

The study population comprised participants in the phase 1 pilot study of the Carbohydrate Alternatives and Metabolic Phenotypes (CAMP) study. The CAMP study is an ongoing population-based study evaluating the precise links between carbohydrates and carbohydrate-rich foods and metabolic profiles, as well as the onset of metabolic diseases, using both traditional epidemiological approaches and metabolomics techniques. Preliminary analyses will be conducted in a phase 1 sample (104 adults living in Xi'an), and then evaluation will continue in phase 2 samples, which are other established cohorts among the general population of northwest China.

Information about the phase 1 CAMP study was disseminated via the WeChat smartphone application. Eligible participants were university students or staff aged 18–35 years, with body mass index (BMI) at least 18.5 kg/m². Exclusion criteria were: 1) pregnancy; 2) clinical biomarkers for liver and kidney function outside reference ranges; 3) current severe cardiovascular diseases, infectious diseases, or

cancer; and 4) current use of antidepressants. The study was approved by the Ethical Committee of Xi'an Jiaotong University Health Science Center, and all participants provided written informed consent.

Data collection

Eligible men and women were invited to participate in a physical examination at the Department of Epidemiology, School of Public Health, Xi'an Jiaotong University, on weekends during March and April of 2018. Anthropometry measurement and blood sample collection were performed by trained health workers from the First Affiliated Hospital of Xi'an Jiaotong University. Demographic and lifestyle information (smoking, alcohol consumption, and physical activity) were collected using questionnaires. Height was measured to the nearest 0.1 cm using a portable stadiometer, with participants wearing light clothing and no shoes. Waist circumference was measured using a measuring tape (Seca 201), at the midpoint between the lowest rib and the iliac crest, to the nearest 0.1 cm. Body weight was measured using a body composition analyzer (Tanita BC210), to the nearest 0.1 kg. BMI was calculated as weight in kilograms divided by the square of height in meters. Blood pressure was measured twice after at least 5 minutes' rest, using a digital monitor (Omron HEM-7124); the average of the two measurements was used in the analysis.

Dietary information was collected using a food frequency questionnaire with five response options (daily, 4 to 6 days per week, 1 to 3 days per week, monthly, or never; the first two groups were combined in analysis due to limited participants number in each), as previously applied in the China Kadoorie Biobank¹⁷. The questionnaire included six categories (beverages, staple foods, animal-based foods, plant-based food, dairy products, and other foods), with a total 27 items. The intake amount (grams) of each food item on each occasion was also estimated by participants. The average daily intake of each item was then calculated by combining the intake frequency and intake amount on each occasion. For staple foods, we collected information on intakes of rice/flour products and coarse food grains. Coarse food grain was defined as any grain food or various beans (mainly mung bean, red bean, and kidney bean, etc.) other than rice or wheat products.¹¹.

Statistical analysis

The characteristics of participants are presented as coarse food grain intake frequency, mean \pm standard deviation (SD), or percentage, as appropriate. Between-group differences were tested using general linear model (GLM) adjusted for age and sex when appropriate. The associations between frequency of coarse food grain intake and blood pressure are presented as adjusted means for each category, with a statistical test for trend, using the GLM; Dunnett's test was used to compare each group with the

“Never/Rarely” group. Covariates included age, sex, education attainment (high school, undergraduate, or graduate students), smoking status (current smoker or nonsmoker), alcohol consumption (current drinker or non-drinker), BMI and physical activity level (metabolic equivalent task-hr/wk). The association between estimated daily intake of coarse food grains (continuous variable) with blood pressure was also evaluated using the GLM. All statistical analysis was conducted with SAS 9.3 (SAS Institute, Cary, NC, USA). A two-sided P value < 0.05 was considered statistically significant.

Results

The participant characteristics are presented in **Table 1**. The mean age of participants was 22.8 ± 3.7 years; 36.5% of participants were men, and 82.7% were undergraduate students, with no apparent difference among the groups of coarse food grain intake. We found that 12.5 % of our participants have regular habits of coarse food grain intake (at least 4 days/Wk). No difference was detected for smoking and drinking habits, consumption frequencies of rice/flour products and red meat, and physical activity levels, according to levels of coarse food grain consumption. Interestingly, we observed that participants who had higher frequencies of coarse food grain intake had lower BMI, weight, SBP, and DBP than those with lower intakes of coarse food

grains. SBP and DBP showed a positive association with age group in our population of young adults (**Figure 1**).

As shown in **Figure 2**, after adjusting for age, sex, education, smoking, alcohol consumption, and BMI, higher frequency of coarse food grain consumption was associated with lower SBP and DBP (P values for trend were 0.006 and 0.015, respectively). Further adjustment for physical activity levels did not materially change the association patterns (P values for trend were 0.007 and 0.017, respectively). By comparing each group with “Never or rarely” group, only those who consumed at least four days/Wk showed significant lower SBP ($P = 0.005$) and DBP ($P = 0.045$) (Supplemental table 1).

We also evaluated the associations for estimated daily intake of coarse food grains (**Table 2**). Similarly, coarse food grain intake was inversely associated with both SBP (β coefficient \pm SE = -0.039 ± 0.017 , $P = 0.024$) and DBP after multiple adjustment (β coefficient \pm SE = -0.033 ± 0.013 , $P = 0.016$). We also conducted stratified analysis by sex, age group, and BMI level. The overall direction of the associations was comparable to that in the main analysis, with some associations no longer significant (**Table 2**). No significant interaction was detected among stratified groups (Supplemental table 2).

Discussion

In this study, we observed an inverse association between the frequency of coarse food grain intake and both SBP and DBP among young Chinese adults. This association appears to be independent of other traditional lifestyle factors including adiposity and physical activity level.

Coarse food grains are grains or beans other than rice and wheat products¹¹. Consumption of coarse food grains are widely accepted in Chinese culture. In fact, most people in China are more familiar with coarse food grains than whole grains, although they share common nutrient facts, that both of them are abundant in B vitamins, fiber, and some trace minerals. The most frequently consumed coarse food grains (millet, corn, oat, adlay, buckwheat, and so on)¹² and their products are inexpensive and widely available in many markets in China. On the contrary, so-called whole grain foods, like brown rice or whole wheat toast, are mostly available in specialty shops and are usually more expensive than refined grains¹³. Our results suggest potential benefits of coarse food grain intake on blood pressure, although ours is a cross-sectional study with a limited sample size. Further interventional studies or large cohort studies are needed to confirm this association and provide more robust evidence to support the recommendation of the Dietary Guidelines for Chinese Residents to maintain adequate daily intake of coarse food grains.

To our best knowledge, no previous studies ever reported an association between coarse food grain intake and blood pressure. However, there are several reports suggesting that whole grains may have beneficial effects on blood pressure control. In a cross-sectional study among 1968 French adults aged 18 to 74 years, fiber and whole grain intake were both inversely associated with SBP⁶. Similarly, in an analysis based on data from the NutriNet-Santé Cohort including 80,426 French adults with mean age 42 years, higher whole grain intake was associated with a 16% reduction in hypertension risk⁵. Results from clinical trials have also indicated beneficial effects of whole grain supplementation on blood pressure, yet in middle-aged individuals with elevated body weight⁷ or diabetes¹⁸. In those previous findings, we did not find information regarding the relationship between diet and blood pressure that is specific to young adults. Nevertheless, the protective factors for blood pressure in young adults should not be neglected, given their higher cardiovascular risk attributable to hypertension¹⁴ and lower rates of awareness and treatment of hypertension¹⁵ than those of older adults. Our results suggested an inverse association between coarse food grain intake and blood pressure among university students and young faculty, which may call for further investigation of preventive approaches that underscore the physiologic mechanisms of blood pressure homeostasis among young adults.

Functional abnormality of the renin–angiotensin–aldosterone system (RAAS) is a substantial cause of blood pressure elevation, especially in young people who may still have good arterial elasticity and are therefore more likely to have normal SBP and relatively high DBP¹⁹. The precise mechanism for the inverse association between coarse food grain intake and blood pressure is unclear. However, a recent study in hypertensive mice suggested that a fiber-rich diet may lead to changes in the gut microbiota toward a protective profile in the development of cardiovascular disease and may also downregulate a gene network of the RAAS in the kidneys²⁰, which may substantially contribute to the control of blood pressure. The effects of oat fiber intake on blood pressure have also been investigated in several human studies. Keenan et al. observed that SBP and DBP were reduced by 7.5 and 5.5 mmHg, respectively, after daily consumption of 5.5 g oat β -glucan for 6 weeks in 18 untreated hypertensive patients²¹. Similar results were also observed in subsequent studies that included various fiber sources, larger sample size, and longer intervention duration²². Taken together, the potentially beneficial effects of coarse food grain intake on blood pressure control may be mediated, at least partly, by its fiber richness.

Our cross-sectional analysis was conducted among a small group of participants; hence, we could not exclude the possibility that the captured association was observed by chance. However, the potentially beneficial effects of coarse food

grains on blood pressure might be explained by related biological mechanisms. Given the wide availability of coarse food grain products in China and the emphasis on coarse food grain intake in the Dietary Guidelines for Chinese Residents (2016), the beneficial evidence for consumption of coarse food grains is likely to be of great public health importance, once the effects are confirmed in further larger studies.

Another limitation in our analysis is that we used a food frequency questionnaire to collect food category information. We were unable to adjust for total energy intake in our regression models owing to a lack of data. Nevertheless, total energy intake is in accordance with the requirement of energy expenditure, part of which is physical activity²³. In our analysis, with or without adjustment for physical activity level, the overall direction of the association was not substantially changed. Given limited sample size, we cannot exclude the possibility that some results, especially the stratified data were captured by chance. Admittedly, the associations need to be tested in future larger studies with available total energy data. Moreover, without detailed data of coarse food grain intake frequencies, we could not provide information on which specific coarse food grains are most closely associated with blood pressure; further investigation of this question is among our priority research plans.

To summarize, the findings of our study suggested that the frequency of coarse food grain intake was inversely associated with blood pressure among young Chinese adults. Prospective studies or interventional studies are needed to confirm the potentially beneficial effects of coarse food grain intake on blood pressure control, to provide additional evidence for revision of the dietary guidelines in China, where a quarter of adults are currently affected by hypertension.

Disclosure

The authors have no conflicts of interest to declare.

Authors' contributions

X LIU and X LIAO designed the research; X LIU, X LIAO, X DING, B GAO, H WANG, X ZHAO, Y LIU, L FENG, and W ABDULKADI participated in the data collection, data cleaning and analysis; X LIU, W GAN, and X LIAO wrote the paper; and all authors read and revised the paper. X LIU has primary responsibility for the final content. All authors read and approved the final manuscript as submitted.

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Figure legends**Figure 1 Mean blood pressure, by age.**

DBP, diastolic blood pressure, SBP, systolic blood pressure.

Figure 2 Adjusted mean SBP and DBP, by coarse food grain intake frequency.

SBP (A), systolic blood pressure, DBP (B), diastolic blood pressure. Model 1: adjusted for age, sex education, smoking, alcohol consumption, body mass index; Model 2: additionally adjusted for physical activity.

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Table 1 Characteristics of the participants by the frequency of coarse grain consumption.¹

Characteristics	Consumption of coarse food grains					<i>P</i>
	All participants (<i>n</i> = 104)	Never or Rarely (<i>n</i> = 22)	Monthly (<i>n</i> = 26)	1-3 Days/Wk (<i>n</i> = 43)	4-7 Days/Wk (<i>n</i> = 13)	
Estimated daily intake of coarse grain (g)	23.7 ± 49.1	NA	7.9 ± 4.9	28.0 ± 38.2	81.2 ± 101.3	<0.001
Age (years)	22.8 ± 3.7	22.8 ± 3.9	22.2 ± 2.3	23.0 ± 4.3	23.0 ± 3.7	0.823
Male (%)	36.5	40.9	34.6	37.2	30.8	0.936
Education attainment (%)						0.569
High school	2.9	0	0	4.7	7.7	
University or college (Undergraduate)	82.7	90.9	84.6	79.1	76.9	
University (Graduate or above)	14.4	9.1	15.4	16.3	15.4	
Non-smokers (%)	97.1	95.4	100.0	95.4	100.0	0.412
Current alcohol intake (%)	36.5	31.8	46.2	32.6	38.5	0.673
Physical activity (MET-hr/Wk) ²	321.7 ± 263.6	208.1 ± 181.6	347.2 ± 171.1	376.0 ± 337.1	287.9 ± 216.6	0.086
Body mass index (kg/m ²)	21.7 ± 2.9	22.5 ± 3.7	21.3 ± 2.4	21.8 ± 2.9	20.8 ± 2.1	0.380

Weight (kg)	60.0 ± 11.7	63.0 ± 15.0	58.5 ± 10.4	60.2 ± 11.6	57.5 ± 8.2	0.449
Systolic blood pressure (mmHg)	111.7 ± 12.2	115.1 ± 13.8	113.9 ± 14.0	111.1 ± 9.8	103.8 ± 9.6	0.003
Diastolic blood pressure (mmHg)	73.0 ± 7.6	74.7 ± 8.9	74.8 ± 8.0	72.4 ± 6.5	68.5 ± 7.1	0.016
Regular consumption of foods (%) ³						
Rice or flour products	99.0	100.0	100.0	100.0	92.3	0.238
Red meat	43.3	36.3	38.5	46.5	53.9	0.694

1, Values are mean ± SD or % as indicated.

2, MET indicate metabolic equivalent.

3, Regular consumption was defined as consumption at least 4 days per week.

Table 2 Associations between daily intake of coarse grain with SBP and DBP. ¹

	Estimated daily intake (g)	SBP			DBP		
		β coefficient	R ²	P	β coefficient	R ²	P
		\pm SE		value	\pm SE		value
All participants	23.7	-0.039 \pm 0.017	0.60	0.024	-0.033 \pm 0.013	0.40	0.016
Male (<i>n</i> = 38)	32.0	-0.047 \pm 0.025	0.33	0.073	-0.018 \pm 0.020	0.36	0.337
Female (<i>n</i> = 66)	19.0	-0.029 \pm 0.027	0.25	0.285	-0.049 \pm 0.022	0.21	0.031
Age \geq 21.5 years (median, <i>n</i> = 52)	28.3	-0.032 \pm 0.027	0.65	0.254	-0.040 \pm 0.022	0.51	0.069
Age < 21.5 years (median, <i>n</i> = 52)	19.1	-0.054 \pm 0.024	0.56	0.030	-0.033 \pm 0.018	0.14	0.078
BMI \geq 21.2 kg/m ² (median, <i>n</i> = 51)	19.1	-0.030 \pm 0.041	0.51	0.472	-0.043 \pm 0.033	0.33	0.194
BMI < 21.2 kg/m ² (median, <i>n</i> = 53)	28.2	-0.041 \pm 0.017	0.50	0.020	-0.027 \pm 0.013	0.22	0.047

1, Adjusted for age, sex, education, smoking, alcohol drinking, BMI, and physical activity levels except for each sex group, sex was removed from the model.

Figure 1

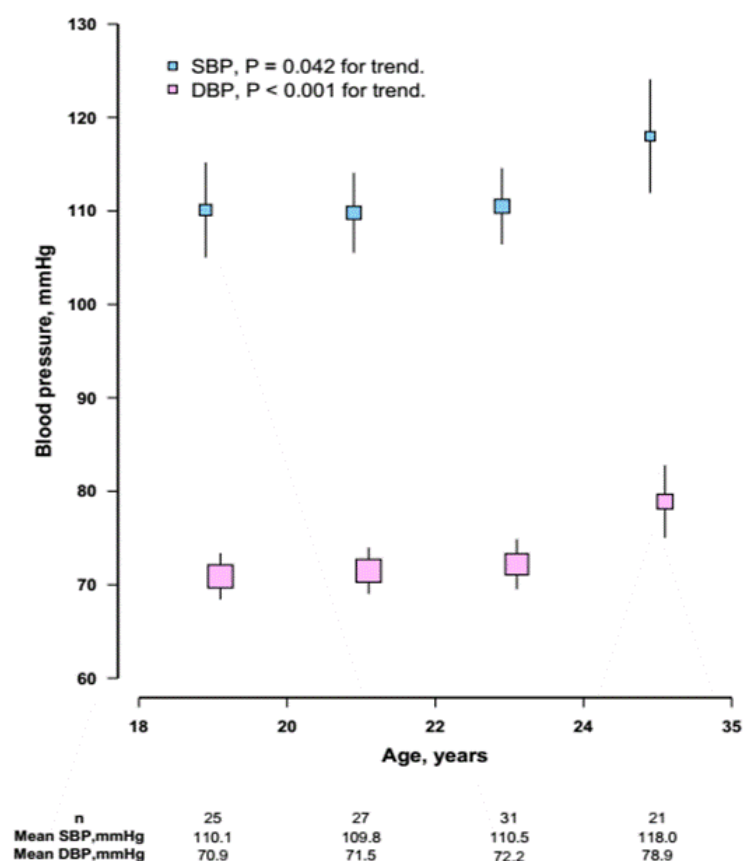


Figure 2

