

A higher ratio of beans to white rice is associated with lower cardiometabolic risk factors in Costa Rican adults^{1–3}

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ABSTRACT

Background: A high intake of white rice is associated with the metabolic syndrome and type 2 diabetes. Costa Ricans follow a staple dietary pattern that includes white rice and beans, yet the combined role of these foods on cardiometabolic risk factors has not been studied.

Objective: We aimed to determine the association between intake of white rice and beans and the metabolic syndrome and its components in Costa Rican adults ($n = 1879$) without diabetes.

Design: Multivariate-adjusted means were calculated for components of the metabolic syndrome by daily servings of white rice and beans (<1 , 1 , or >1) and by the ratio of beans to white rice. The OR for the metabolic syndrome was calculated by substituting one serving of beans for one serving of white rice.

Results: An increase in daily servings of white rice was positively associated with systolic blood pressure (BP), triglycerides, and fasting glucose and inversely associated with HDL cholesterol (P -trend <0.01 for all). An increase in servings of beans was inversely associated with diastolic BP ($P = 0.049$). Significant trends for higher HDL cholesterol and lower BP and triglycerides were observed for 1:3, 1:2, 1:1, and 2:1 ratios of beans to white rice. Substituting one serving of beans for one serving of white rice was associated with a 35% (95% CI: 15%, 50%) lower risk of the metabolic syndrome.

Conclusion: Increasing the ratio of beans to white rice, or limiting the intake of white rice by substituting beans, may lower cardiometabolic risk factors. *Am J Clin Nutr* 2011;94:869–76.

INTRODUCTION

White rice is a staple food across the world. In Latin America countries, per capita consumption of white rice has tripled in the past 60 y, becoming the most popular grain and replacing many of the endogenous crops (1). Despite its widespread use, white rice has been the focal point of recent studies and has been shown to be associated with an increased risk of type 2 diabetes (2–4). White rice is a refined processed carbohydrate with a high glycemic index and glycemic load (5); the strong postprandrial rise in blood glucose in response to its consumption and the loss of magnesium, dietary fiber, and other phytonutrients during processing may explain its association with diabetes (2, 6).

In contrast with the findings with white rice, intake of legumes has been associated with a protective effect against chronic diseases through various mechanisms. Legumes are low in saturated fat, have a low glycemic index, have a high mineral availability, and have a high content of dietary fiber, α -linolenic acid, and

protein (7, 8). Specifically, an increased intake of beans has been shown to be associated with a lower risk of myocardial infarction (9); lower serum total cholesterol, LDL cholesterol, body weight, and systolic BP;⁴ and a smaller waist circumference (10, 11), which are established biomarkers for cardiovascular disease, the metabolic syndrome, and type 2 diabetes.

In most Latin American countries, people traditionally consume white rice in combination with beans. A staple dietary pattern that included white rice and beans was identified in Costa Rican adults (12). Whereas white rice represents the main source of energy in Costa Ricans (13, 14), and beans are a major source of protein, the intake of beans has been declining with urbanization (15). Because the prevalence of diabetes is increasing worldwide (16), with a 140% increase expected by 2025 in Costa Rica (17), it is imperative to understand the potential contrasting effects of white rice and beans on risk factors for diabetes, such as the metabolic syndrome, especially in populations with substantial consumption of both foods. Yet, the combined association of these foods on cardiometabolic risk factors has not been studied. Thus, we aimed to determine the association between intake of white rice and beans and the metabolic syndrome and its components in Costa Rican adults without type 2 diabetes.

SUBJECTS AND METHODS

Study population

This study included control subjects who participated in a population-based case-control study of heart disease conducted in Costa Rica from 1994 to 2004 (14, 18). Control subjects were randomly selected by using data from the National Census and Statistics Bureau of Costa Rica, matched for age (± 5 y), sex, and area of residence (county) to case survivors of a first acute myocardial infarction. Control subjects were excluded if they had ever had a myocardial infarction or if they were physically or mentally unable to participate. The participation rate for

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⁴ Abbreviations used: ATP III, Adult Treatment Panel III; BP, blood pressure; FFQ, food-frequency questionnaire.

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control subjects was 88%. All subjects provided written informed consent. The Human Subjects Committee of Harvard School of Public Health and University of Costa Rica approved this study.

Data collection

Details of the methods were described previously (9, 18, 19). Briefly, trained personnel conducted home interviews to assess sociodemographic characteristics, lifestyles behaviors, and medical histories using a close-ended questionnaire. Anthropometric measurements, including weight, height, waist circumference, and BP were measured in duplicate, whereas the subjects wore light clothing and no shoes; the average was recorded. BMI was calculated by dividing the weight by the squared height of a subject (kg/m^2). Total physical activity was calculated by multiplying the frequency, duration, and intensity (in metabolic equivalents) of each physical activity level and then summing up energy expenditure from all activities. The subjects provided a blood sample after fasting overnight. Blood samples were collected into tubes containing 0.1% EDTA and were stored in a cooler at 4°C to be transported to the fieldwork station within 4 h. Blood was centrifuged at $1430 \times g$ for 20 min at 4°C to separate plasma. Plasma samples were stored at -80°C and, within 6 mo of collection, were transported over dry ice to the Harvard School of Public Health for analysis. Plasma triacylglycerol and HDL cholesterol were measured enzymatically (Boehringer-Mannheim) by using a Roche Cobas Mira Plus autoanalyzer (Roche Diagnostics Systems). Blood glucose was measured by using Accu-Check II Blood Glucose Monitor with Chemstrip bG Test Strips (Boehringer-Mannheim).

Dietary assessment

Dietary data were collected with a semiquantitative FFQ that was developed and validated specifically for Costa Ricans (20). Standardized serving sizes were obtained from the School of Nutrition at the University of Costa Rica (21). The FFQ asked the subjects to specify the portion size and frequency of white rice and bean intakes by asking how frequently they consumed a serving of each food during the previous years. Categories for frequency were <1 time/mo or never, 1–3 times/mo, 1 time/wk, 2–4 times/wk, 5–6 times/wk, 1 time/d, 2–3 times/d, 4–5 times/d, and ≥ 6 times/d. A serving of rice corresponds to 0.66 cups (~ 150 g), and a serving of beans corresponds to 0.33 cups (~ 86 g). Mixed dishes containing either food (ie, gallopinto) were not included because consumption is relatively low in the studied population (median intake: 1 serving/wk) compared with that of beans and white rice alone. The FFQ also asked subjects about the type of oil used for cooking and frying at home and the duration of use (22). Reported nutrient intake is hereby referred to as “intake.”

Metabolic syndrome

Metabolic syndrome was defined according to ATP III guidelines (23). A subject with the metabolic syndrome met ≥ 3 of the following criteria: abdominal obesity (>102 cm in men, >88 cm in women), elevated BP ($>130/85$ mm Hg), high triglycerides (≥ 1.69 mmol/L, or 150 mg/dL), low HDL cholesterol (men: <1.03 mmol/L, or 40 mg/dL; women: <1.29 mmol/L or 50 mg/dL), and impaired fasting glucose (≥ 5.6 mmol/L, or 100 mg/dL). Fasting glucose criteria was lowered from the original cutoff to

reflect revised guidelines (24). Subjects using medication for hypertension or diabetes were considered to meet the criteria for elevated BP and impaired fasting glucose, respectively.

Statistical analysis

The analysis was conducted by using SAS software version 9.1 (SAS Institute Inc). Of the 2270 control subjects with available FFQ data, 328 were excluded for a history of diabetes. After subjects with missing data on the metabolic syndrome and potential covariates were excluded, 1879 control subjects were available and were included in this analysis. The frequency of intake of daily servings of white rice and beans was defined according to 3 categories: <1 time/d, 1 time/d, or >1 time/d. A variable for the ratio of beans to white rice (daily servings) was created by using the following categories: 1:3, 1:2, 1:1, and 2:1 servings. Individual nutrients were adjusted for total energy intake by using the regression residual method (25, 26). Quintiles were created for continuous energy-adjusted nutrient variables and other continuous covariates. Values of plasma glucose and triacylglycerols were log-transformed to restore normal distribution.

Differences in the distribution of sociodemographic, lifestyle, dietary, and physiologic factors by metabolic syndrome status were tested by using *t* tests for continuous variables and chi-square tests for categorical variables. Age-adjusted differences in distribution for those same measures, by categories of daily servings of white rice and beans, were calculated by ANOVA. Multivariate linear regression was used to obtain adjusted means for components of the metabolic syndrome by daily servings of white rice or beans. Potential confounders tested in the models included age, sex, area of residence, income, alcohol intake, smoking status, physical activity, fiber intake, type of cooking oil, and total energy; white rice was added as a covariate when differences in outcomes by bean intake were tested. The other models tested did not differ from those shown. *P*-trend values by increasing categories of white rice or bean intake and by the ratio of beans to white rice were determined by assigning the median of each category to a subject in the respective category of intake or ratio and then entering the resulting continuous variable into the model.

ORs and 95% CIs for the metabolic syndrome and its components were estimated for substituting one serving of beans for one serving of white rice, as previously described (2). Briefly, white rice and beans were included as continuous variables in the same model. The difference between regression coefficients was used to derive the OR for the substitution. The substitution analysis, based on statistical modeling of observational data, estimated the potential effect of substituting one macronutrient or food for another while holding total energy intake constant. Although such an analysis does not provide direct evidence for causality, it fosters the design of nutrition intervention studies to test the hypothesis. All tests were considered significant at $P < 0.05$.

RESULTS

The general characteristics of the study participants by metabolic syndrome status are shown in **Table 1**. Nearly 30% of the control subjects without previously reported type 2 diabetes met the criteria for the metabolic syndrome; these

subjects were more likely to be women and older and less likely to smoke and be physically active. Subjects with the metabolic syndrome consumed fewer calories and beans and were more likely to use corn or sunflower oil for cooking instead of palm oil.

Age-adjusted characteristics across categories of daily servings of white rice and beans to evaluate potential confounding factors are shown in **Table 2**. Nearly 63% of subjects reported consuming >1 serving of white rice per day, whereas only 39% reported consuming beans at that frequency. Those consuming more daily servings of white rice were younger, had lower incomes, and were more likely to be men, live in rural areas, smoke, and be more physically active. The distribution for those characteristics across daily servings of beans was similar as for white rice, except for age, for which no significant differences were observed. Higher intakes of energy, total carbohydrates, dietary fiber, beans, and palm and soy oil but lower intakes of alcohol and corn/sunflower oil were observed for increasing daily servings of white rice. Similar trends were observed for intake of beans, except for the use of soy oil (NS). Those con-

suming >1 serving white rice/d had a lower BMI and HDL cholesterol, but a higher systolic BP and fasting glucose; those at this same frequency of intake of beans had a lower BMI, waist circumference, diastolic BP, HDL cholesterol, and prevalence of the metabolic syndrome.

Multivariate-adjusted means for components of the metabolic syndrome by daily servings of white rice and beans are shown in **Table 3**. After control for potential covariates, including BMI, a trend for higher systolic BP, plasma triglycerides, and fasting glucose but a lower HDL cholesterol was observed by increasing daily servings of white rice. An increase in daily servings of beans was associated with a trend for lower waist circumference, diastolic BP, and plasma triglycerides and higher HDL cholesterol, after adjustment for all covariates except BMI. Only a trend for lower diastolic BP remained significant (P -trend = 0.049) after control for BMI.

Multivariate analysis was conducted to determine the association between cardiometabolic components and the ratio of daily servings of beans to white rice (**Figure 1**). Significant trends were observed for higher HDL cholesterol (P -trend =

TABLE 1
General characteristics of Costa Rican adults by metabolic syndrome status ($n = 1879$)¹

	No metabolic syndrome ($n = 1331$; 70.8%)	Metabolic syndrome ($n = 548$; 29.2%)	All subjects ($n = 1879$)
Demographic and lifestyle factors			
Age (y)	56.4 ± 11.6 ²	59.6 ± 10.3 ³	57.3 ± 11.3
Sex (% female)	19.4	37.6 ³	24.7
Area of residence (% urban)	41.0	37.4	40.0
Income (\$/mo)	578 ± 430	587 ± 420	580 ± 427
Physical activity (METs)	36.9 ± 17.8	34.0 ± 13.6 ⁴	36.0 ± 16.8
Current smoker (%)	25.2	16.1 ³	22.1
Dietary factors			
Total energy (kcal)	2495 ± 759	2415 ± 789 ⁵	2474 ± 768
Alcohol (g/d) ⁶	6.6 ± 15.2	5.4 ± 12.1	6.3 ± 14.4
Total carbohydrate (% of energy)	55.8 ± 7.5	56.4 ± 7.1	55.5 ± 7.4
Fiber (g/d) ⁶	23.3 ± 6.2	23.8 ± 5.8	24.0 ± 6.1
White rice (servings/d)	1.9 ± 0.8	1.9 ± 0.8	1.9 ± 0.8
Beans (servings/d)	1.4 ± 1.0	1.2 ± 0.9 ³	1.4 ± 1.0
Beans:white rice servings (%)			
1:3	10.8	15.5 ⁴	12.2
1:2	25.5	29.2	26.6
1:1	61.1	52.9	58.7
2:1	2.6	2.4	2.5
Type of cooking oil (% used)			
Corn/sunflower oil	19.1	26.1 ⁴	21.1
Palm oil	25.0	18.4	23.1
Soy oil	52.1	52.5	52.2
Biomarkers			
BMI (kg/m ²)	25.0 ± 3.4	29.2 ± 4.1 ³	26.2 ± 4.2
Waist circumference (cm)	87.6 ± 8.8	96.7 ± 10.0 ³	90.2 ± 10.0
Systolic BP (mm Hg)	131.1 ± 20.9	145.6 ± 21.6 ³	135.4 ± 22.1
Diastolic BP (mm Hg)	79.3 ± 9.6	87.6 ± 11.2 ³	81.7 ± 10.7
HDL cholesterol (mg/dL)	41.9 ± 9.0	38.3 ± 6.6 ³	40.9 ± 8.6
Plasma triglycerides (mg/dL)	201.8 ± 128.3	244.1 ± 107.7 ³	214.2 ± 123.0
Fasting glucose (mg/dL)	73.6 ± 18.7	82.5 ± 27.1 ³	76.2 ± 21.9

¹ BP, blood pressure; METs, metabolic equivalents.

² Mean ± SD (all such values).

³ $P < 0.0001$.

⁴ $P < 0.01$.

⁵ $P < 0.05$.

⁶ Energy-adjusted by using the residuals method.

TABLE 2

General characteristics of Costa Rican adults by daily servings of white rice and beans ($n = 1879$)¹

	White rice				Beans			
	<1 serving/d	1 serving/d	>1 serving/d	<i>P</i> value	<1 serving/d	1 serving/d	>1 serving/d	<i>P</i> value
Subjects [<i>n</i> (%)]	132 (7.0)	568 (30.2)	1179 (62.8)		584 (31.1)	570 (30.3)	725 (38.6)	
Sociodemographic factors								
Age (y)	57.9 ± 11.2 ²	59.1 ± 10.9	56.4 ± 11.4	<0.0001	56.7 ± 11.7	58.8 ± 11.4	56.7 ± 10.8	0.271
Sex (% female)	32.2	32.0	20.4	<0.0001	33.4	24.7	17.7	<0.0001
Area of residence (% urban)	58.3	46.8	34.6	<0.0001	50.7	40.4	30.9	<0.0001
Income (\$/mo)	881 ± 36	658 ± 18	509 ± 12	<0.0001	724 ± 17	595 ± 18	452 ± 16	<0.0001
Physical activity (METs)	32.5 ± 1.4	33.0 ± 0.7	37.9 ± 0.5	<0.0001	32.8 ± 0.7	34.7 ± 0.7	39.7 ± 0.6	<0.0001
Current smoker (%)	18.5	19.7	24.3	0.015	18.8	20.5	27.1	0.0001
Dietary factors								
Total energy (kcal/d)	2199 ± 63	2162 ± 31	2655 ± 21	<0.0001	2202 ± 30	2373 ± 30	2772 ± 27	<0.0001
Alcohol (g/d) ³	9.3 ± 1.3	8.0 ± 0.6	5.1 ± 0.4	<0.0001	7.2 ± 0.6	7.5 ± 0.6	4.6 ± 0.5	0.0001
Total carbohydrates (% of energy)	50.9 ± 0.6	54.8 ± 0.3	56.4 ± 0.2	<0.0001	55.0 ± 0.3	55.0 ± 0.3	56.5 ± 0.3	<0.0001
Fiber (g/d) ³	21.7 ± 0.5	22.4 ± 0.3	23.5 ± 0.2	<0.0001	20.3 ± 0.2	22.1 ± 0.2	26.0 ± 0.2	<0.0001
White rice (servings/d)	0.5 ± 0	1.0 ± 0	2.5 ± 0	<0.0001	1.5 ± 0.03	1.7 ± 0.03	2.4 ± 0.02	<0.0001
Beans (servings/d)	0.4 ± 0.07	0.8 ± 0.03	1.7 ± 0.02	<0.0001	0.3 ± 0	1.0 ± 0	2.5 ± 0	<0.0001
Use of sunflower/corn oil (%)	33.3	26.2	17.2	<0.0001	26.0	23.8	14.9	<0.0001
Use of palm oil (%)	8.3	18.3	26.9	<0.0001	14.7	21.5	30.9	<0.0001
Use of soy oil (%)	43.3	50.8	53.6	0.047	50.8	52.2	53.9	0.486
Biomarkers								
BMI (kg/m ²)	26.5 ± 0.4	26.6 ± 0.2	25.9 ± 0.1	0.002	26.6 ± 0.2	26.6 ± 0.2	25.6 ± 0.2	<0.0001
Waist circumference (cm)	90.4 ± 0.9	90.3 ± 0.4	90.2 ± 0.3	0.793	90.3 ± 0.4	91.0 ± 0.4	89.5 ± 0.4	0.044
Systolic BP (mm Hg)	130 ± 1.7	135 ± 0.8	136 ± 0.6	0.005	134 ± 0.8	136 ± 0.8	135 ± 0.7	0.871
Diastolic BP (mm Hg)	80.9 ± 0.9	81.7 ± 0.5	81.8 ± 0.3	0.552	82.0 ± 0.4	82.4 ± 0.4	81.0 ± 0.4	0.040
HDL cholesterol (mg/dL)	42.8 ± 0.7	42.3 ± 0.4	39.9 ± 0.2	<0.0001	41.4 ± 0.4	41.0 ± 0.4	40.3 ± 0.3	0.016
Plasma triglycerides (mg/dL)	193 ± 11	215 ± 5	216 ± 4	0.208	215 ± 5	217 ± 5	211 ± 5	0.481
Fasting glucose (mg/dL)	74.3 ± 1.9	75.0 ± 0.9	77.1 ± 0.6	0.034	76.8 ± 0.9	76.0 ± 0.9	76.0 ± 0.8	0.603
Metabolic syndrome (%)	30.8	30.4	28.4	0.334	34.7	29.8	24.2	<0.0001

¹ Values are age-adjusted. BP, blood pressure; METs, metabolic equivalents.² Mean ± SD (all such values).³ Energy-adjusted by using the residuals method.

0.001) and for lower systolic BP (P -trend = 0.020), diastolic BP (P -trend = 0.015), and plasma triglycerides (P -trend = 0.010) with increasing ratios of beans to white rice, after adjustment for potential confounders, including BMI. Subjects who consumed a ratio of 2 servings of beans to 1 serving of white rice had lower plasma triglycerides than did those who consumed 1:1, 1:2, and 1:3 servings of beans to white rice [154 (21, 24) compared with 185 (12, 12), 188 (13, 14), and 201 (17, 18), respectively]. Compared with subjects who consumed a ratio of one serving of beans to one serving of white rice, those who consumed a 1:3 ratio had a significantly higher diastolic BP [80 (0.1) compared with 78 (0.7)] but a lower HDL cholesterol concentration [41 (0.8) compared with 43 (0.6)]; no significant differences were observed against the highest ratio.

After adjustment for potential covariates, the substitution of one serving of beans for one serving of white rice was associated with a 35% (95% CI: 15, 50%) lower odds of having the metabolic syndrome, a 33% (95% CI: 14, 49) reduction in the likelihood of having a low HDL cholesterol concentration, and a 45% (95% CI: 10, 66) lower odds of having an elevated fasting glucose concentration, as defined by ATP III guidelines (Figure 2). Adjustment for BMI attenuated these associations slightly, but they remained significant (data not shown). No other cardiometabolic component showed a significant association from the substitution of beans for white rice.

DISCUSSION

This study showed that increasing the ratio of beans to white rice to 2:1 daily servings, or limiting the intake of white rice by substituting beans, may lower cardiometabolic risk factors. We reported a significant adverse association of increasing daily servings of white rice and a protective association of higher intakes of beans on components of the metabolic syndrome—a risk factor for type 2 diabetes. Specifically, a higher frequency of servings of white rice was associated with higher systolic BP, plasma triglycerides, and fasting glucose and with lower HDL cholesterol. However, increasing the servings of beans was associated with a lower diastolic BP. Moreover, substituting one serving of beans for white rice was associated with a 35% lower risk of the metabolic syndrome in Costa Rican adults without type 2 diabetes.

The adverse relation of metabolic conditions with an increased intake of white rice has been reported in other populations. In a large cohort study of women living in the United States, mainly whites, Sun et al (2) showed that a higher intake of white rice was associated with an increased risk of type 2 diabetes. The same conclusion was recently made for Japanese (3) and Chinese (4) women—2 ethnic groups with a high consumption of this carbohydrate; a similar finding was observed in Indians from Chennai in a cross-sectional study (27). For whites and Chinese, the increase in risk of diabetes occurred at 300 g/d (~2 servings/d),

TABLE 3

Multivariate-adjusted means for components of the metabolic syndrome by daily servings of white rice and beans in Costa Rican adults ($n = 1879$)¹

	White rice				Beans			
	<1 serving/d	1 serving/d	>1 serving/d	P-trend	<1 serving/d	1 serving/d	>1 serving/d	P-trend
Waist circumference (cm)								
Model 1 ²	88.3 ± 1.0 ³	88.7 ± 0.7	88.2 ± 0.7	0.523	88.7 ± 0.7	89.0 ± 0.8	87.4 ± 0.8	0.037
Model 2 ⁴	88.4 ± 0.4	88.3 ± 0.3	88.6 ± 0.3	0.228	88.5 ± 0.3	88.5 ± 0.3	88.3 ± 0.3	0.562
Systolic BP (mm Hg)								
Model 1 ²	127 ± 2.2	132 ± 1.5*	133 ± 1.4*	0.010	131 ± 1.6	131 ± 1.7	129 ± 1.7	0.092
Model 2 ⁴	127 ± 2.1	131 ± 1.5*	133 ± 1.4*	0.006	131 ± 1.5	131 ± 1.6	129 ± 1.7	0.156
Diastolic BP (mm Hg)								
Model 1 ²	77.5 ± 1.1	78.6 ± 0.8	79.0 ± 0.8	0.257	78.9 ± 0.8	78.6 ± 0.9	77.1 ± 0.9	0.016
Model 2 ⁴	77.6 ± 1.1	78.5 ± 0.8	79.0 ± 0.7	0.137	78.9 ± 0.8	78.5 ± 0.8	77.4 ± 0.9	0.049
HDL cholesterol (mg/dL)								
Model 1 ²	43.4 ± 0.9	43.3 ± 0.6	41.4 ± 0.6	<0.0001	42.3 ± 0.6	42.4 ± 0.7	43.5 ± 0.7	0.043
Model 2 ⁴	43.4 ± 0.9	43.3 ± 0.6	41.4 ± 0.6*	<0.0001	42.4 ± 0.6	42.5 ± 0.7	43.4 ± 0.7	0.078
Plasma triglycerides (mg/dL)								
Model 1 ²	162 (146, 179) ⁵	187 (174, 201)*	191 (179, 204)*	0.020	184 (171, 198)	181 (168, 196)	170 (157, 185)	0.030
Model 2 ⁴	163 (148, 180)	187 (174, 200)*	192 (180, 205)*	0.009	184 (172, 198)	181 (168, 196)	173 (160, 197)	0.076
Fasting glucose (mg/dL)								
Model 1 ²	70.4 (74.1, 73.9)	71.3 (68.8, 73.8)	73.3 (70.9, 75.7)	0.012	72.1 (69.6, 74.7)	71.5 (68.9, 74.3)	70.8 (68.1, 73.6)	0.310
Model 2 ⁴	70.4 (67.0, 73.9)	71.2 (68.9, 73.7)	73.3 (71.0, 75.7)	0.008	72.1 (69.6, 74.6)	71.3 (68.7, 74.0)	71.1 (68.3, 73.9)	0.486

¹ BP, blood pressure. *Significantly different from the lowest category, $P < 0.05$.² Adjusted for age, sex, area of residence, income, alcohol intake, smoking, physical activity, fiber intake, type of cooking oil, and total energy. Beans were adjusted for white rice intake.³ Mean ± SEM (all such values).⁴ Adjusted as for model 1 plus BMI.⁵ Adjusted geometric mean for back-transformed values; 95% CI in parentheses (all such values).

whereas in Japanese women it occurred at 560 g/d. Here, we reported significant mean differences in some of the cardiometabolic components at a lower intake: 1 serving/d (~150 g/d). Limiting white rice consumption to this smaller amount may be associated with more preventive benefits against metabolic disease. To our knowledge, there are no reports on the role of white rice intake on diabetes or its risk factors in other Latino ethnic groups.

Studies showing a protective effect of beans, the *Phaseolus vulgaris* species commonly consumed in Latin America, are scarce. Most published reports focused on legumes as a group, or specifically on soybeans, which have reported benefits in preventing and treating certain types of cancer, osteoporosis, heart disease, and menopausal symptoms (28). However, soybeans have a nutrient composition different from that of beans: a higher content of protein, fat, and calcium and a lower fiber content and folate availability (28). Their high isoflavones content, which is limited in beans, confers distinctive properties that may explain the unique health benefits of soybeans. Several mechanisms for the protective effect of beans have been proposed, including high fiber and α -linolenic contents but a low saturated fat content (7, 8). We adjusted for dietary fiber in our models. Because Costa Ricans commonly cook beans in oil or add it later, we adjusted for the type of cooking oil. In the current study, a higher frequency of bean intake was associated with a higher use of palm oil, which is high in saturated fat. The significant trend for lower cardiometabolic risk factors with increasing servings of beans remained after adjustment for these potential covariates. Other studies have reported results similar to ours (9–11). Of those studies reporting specific intakes, the benefit was observed at 0.33 (~86 g) to 0.5 (~150 g) cups/d (1–

1.5 servings/d), which agrees with our finding. We observed the most beneficial cardiometabolic profile at >1 serving beans/d, which suggests that recommendations for bean intake may be increased to that amount.

The innovative aspect of our study was the analysis of the role of different ratios of beans to white rice and the substitution of beans for white rice. Sun et al (2) reported that replacing one serving of white rice with brown rice reduced the risk of type 2 diabetes. Noel et al (29) showed that a traditional dietary pattern of rice and beans in Puerto Ricans living in the United States was associated with a lower HDL-cholesterol concentration and the highest likelihood of the metabolic syndrome. The authors did not conduct an analysis separately for the 2 foods, and they suggest that the large contribution of white rice to total energy consumption in this population was likely responsible for the observed results. In an intervention study, Sakuma et al (30) reported a dose-response effect of increasing the amount of barley mixed with white rice on a decreasing postprandial response of plasma glucose and insulin concentrations. Yet, the specific combination of white rice and beans had not been tested until this study was conducted.

A limitation of this study was its cross-sectional nature, which hindered the ability of establishing a causal direction between intake and cardiometabolic profile. Longitudinal studies may clarify the observed associations. Additionally, we did not have data on the type of white rice. The cultivar of the grain and processing and cooking methods influence the glycemic index, amylose and micronutrient contents, and antioxidant capacity of each type of rice (5, 31–33). In turn, these nutritional variations can induce metabolic responses differently. Costa Rica produces ~60% of the rice consumed by its population, with >1000

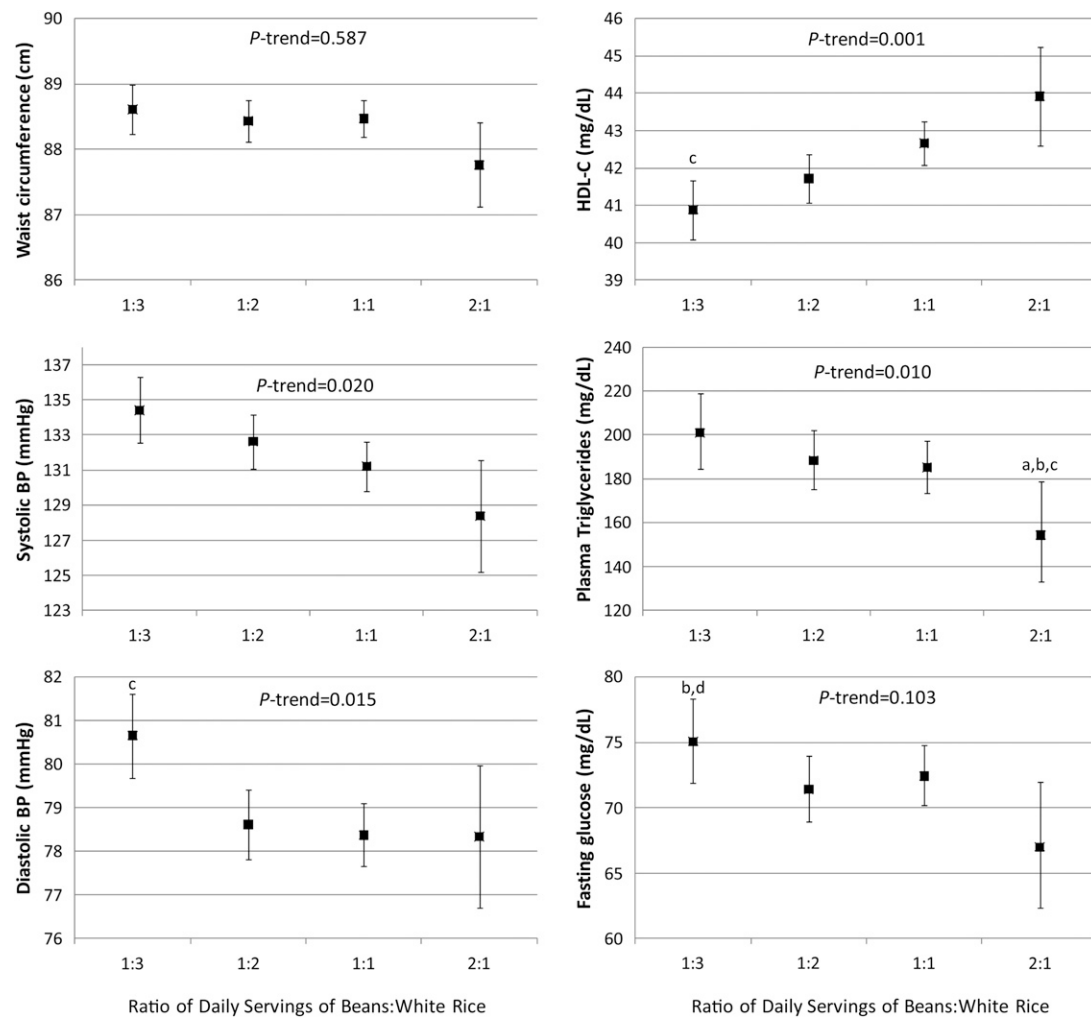


FIGURE 1. Adjusted values for cardiometabolic components by ratio of daily servings of beans to white rice in Costa Rican adults ($n = 1879$). Values are means (\pm SEMs) or adjusted geometric means (95% CIs) for back-transformed plasma triglyceride and fasting glucose concentrations. Lowercase letters indicate significant differences ($P < 0.05$) from the indicated category of beans:white rice: a, 1:3 ($n = 229$); b, 1:2 ($n = 500$); c, 1:1 ($n = 1103$); d, 2:1 ($n = 47$). All models were adjusted for age, sex, area of residence, income, alcohol intake, smoking, physical activity, fiber intake, type of cooking oil, total energy intake, and BMI. BP, blood pressure; HDL-C, HDL cholesterol.

different producers across the country (34). Thus, details on rice cultivar and processing may be difficult to assess. Similarly, *P. vulgaris* includes several varieties of beans. Although our study did not differentiate between types of beans, the most common varieties of beans have an energy content and nutrient composition similar to those of black beans—the type mostly consumed in Costa Rica (9, 28). Thus, our results may be generalized to ethnic groups who consume other types of beans. Future studies may explore any potential variation on cardiometabolic risk factors by type of beans and white rice as well as processing and cooking methods.

Our study had several strengths. First, we used an FFQ that has been validated specifically for Costa Ricans, which likely captured an accurate intake of the exposure foods and other covariate nutrients. More importantly, our study considered a culturally appropriate food (beans) as a possible substitution for white rice in the prevention of cardiometabolic risk factors in Costa Ricans. White rice consumption is widespread in Costa Rica, especially among low-income people. For a potential dietary intervention on prevention of chronic disease to be successful, it is critical to

replace a staple food with another traditional, familiar, and inexpensive food. A focus group study in Chinese adults reported that the main barriers to acceptance of brown rice as a substitute for white rice included texture, taste, and price (35); similar reasons can be expected from other cultures. Brown rice, although shown to lower type 2 diabetes risk in whites when substituted for white rice, is not commonly available or consumed in Latin America; thus, it might not be an appropriate substitution for Costa Ricans. Beans may be a healthy, inexpensive, and culturally appropriate option in reducing cardiovascular risk factors.

Our study may help guide future dietary interventions to prevent type 2 diabetes and other chronic conditions. Note that the analytic models for possible substitutions or changes in the ratios of beans to white rice included energy intake; thus, potential dietary changes should maintain equivalent energy intakes for each participant. Formative research may examine the feasibility of making such dietary changes, particularly regarding food preparation, taste, and cost. In addition, it may serve as a model for similar substitution analysis studies of suitable foods

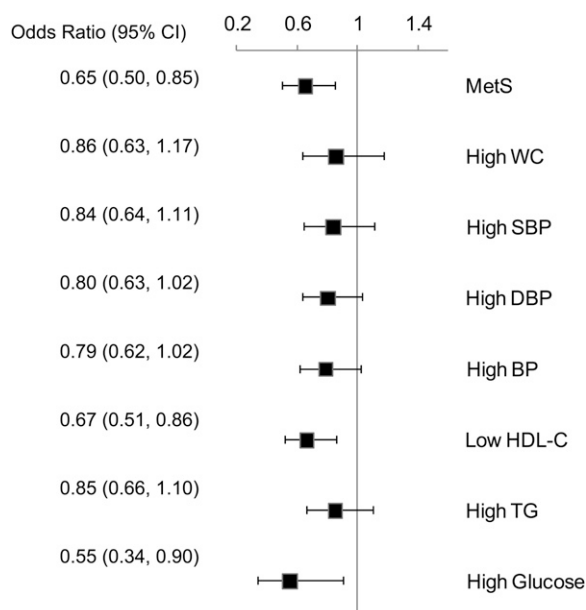


FIGURE 2. ORs and 95% CIs for the risk of the metabolic syndrome (MetS) and its components from substituting one serving of beans for one serving of white rice. The model was adjusted for age, sex, area of residence, income, alcohol intake, smoking, physical activity, fiber intake, type of cooking oil, and total energy. DBP, diastolic blood pressure; HDL-C, HDL cholesterol; SBP, systolic blood pressure; TG, triglycerides; WC, waist circumference.

in other ethnic groups. In conclusion, increasing the ratio of beans to white rice, or limiting the intake of white rice by substituting beans, may lower cardiometabolic risk factors. Public health initiatives on the prevention of type 2 diabetes may consider these results as an appropriate dietary modification, with support from further formative research and intervention studies.

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The authors' responsibilities were as follows—JM, FBH, and HC: designed the research; JM: analyzed the data and wrote the manuscript; and JM, FBH, and HC: interpreted the results and had primary responsibility for the final content. All authors read and approved the final manuscript. None of the authors reported a conflict of interest.

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