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Abstract:	Background and aims: The relationship between carbohydrate quality intake and the Metabolic Syndrome (MetS) is of growing interest. We aim to assess the association between the adherence to a dietary carbohydrate quality index (CQI) with the occurrence of the MetS in a Spanish cohort of working adults. Methods: Cross-sectional study of 2,316 middle-aged men, 50.9 (SD 3.9) years old, with no previous cardiovascular disease, and pertaining to the Aragon Workers' Health Study (AWHS) cohort. Diet was collected with a 136-item semi-quantitative food-frequency questionnaire. The CQI (range 4-15) was based on: dietary fiber intake, a low glycemic index, the ratio of whole grains/total grains, and the ratio of solid carbohydrates/total carbohydrates. The higher the CQI, the healthier the diet. The MetS was defined by using the harmonized National Cholesterol Education Programme-Adult Treatment Panel III (NCEP-ATP III) definition. The associations across 3-point categories of the CQI and the presence of the MetS was examined using logistic regression. Results: An inverse and significant association between CQI and the MetS was found. Fully adjusted odds ratios (OR) for the MetS risk among participants in the 10-12 point category (second highest CQI category) was 0.64 (95%CI: 0.45-0.94), and in the 13-15 point category (highest category) was 0.52 (95%CI: 0.30-0.88), when compared with the 4-6 point category (lowest category). Participants with 10-12 and 13-15 points in CQI showed a lower risk of hypertriglyceridemia: OR 0.61 (95%CI: 0.46-0.81), and 0.48 (95%CI: 0.32-0.71) respectively. Conclusions: Among middle-aged men, a higher adherence to a high-quality carbohydrate diet is associated with a lower prevalence of the MetS. Triglyceridemia is the MetS component that contributed the most to this reduced risk.
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Low-quality carbohydrate intake is associated with a higher prevalence of the metabolic syndrome: The AWHS Study.

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STATEMENTS AND DECLARATIONS

Ethics approval and consent to participate

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the central Institutional Review Board of Aragón (CEICA) (PI07/09). All participants provided written informed consent.

Consent for publication

Not applicable.

Availability of data and materials

Data described in the manuscript, code book, and analytic code will be made available upon request pending on request from the corresponding author. The data are not public due to ethical reasons.

Competing interests

None.

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Author's contributions

The authors' contributions were as follows - AMC: interpretation of data and drafting the manuscript. ML: analysis of data, and critical revision of the manuscript. PGC: study concept and critical revision of the manuscript. BMF study concept and design, interpretation of data, and drafting of the manuscript. JAC, NCG and VMB: revision of the manuscript for intellectual content. AMC, ML, PGC, BMF, JAC, NCG and VMB read and approved the final manuscript.

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LIST OF ABBREVIATIONS

AWHS	Aragon Workers' Health Study
BMI	Body Mass Index
CEICA	Clinical Research Ethics Committee of Aragon
CHD	Coronary Heart Disease
CQI	Carbohydrate Quality Index
CVD	Cardiovascular Disease
FFQ	Food Frequency Questionary
GI	Glycemic Index
HDL-c	High-Density Lipoprotein Cholesterol
LDL-c	Low-Density Lipoprotein Cholesterol
MetS	Metabolic Syndrome
NCEP- ATP III	National Cholesterol Education Programme - Adult Treatment Panel III
Non HDL-c	Non High-Density Lipoprotein Cholesterol
OR	Odds Ratio
RR	Relative Risk
SD	Standard Deviation

ABSTRACT

Background and aims: The relationship between carbohydrate quality intake and the Metabolic Syndrome (MetS) is of growing interest. We aim to assess the association between the adherence to a dietary carbohydrate quality index (CQI) with the occurrence of the MetS in a Spanish cohort of working adults.

Methods: Cross-sectional study of 2,316 middle-aged men, 50.9 (SD 3.9) years old, with no previous cardiovascular disease, and pertaining to the Aragon Workers' Health Study (AWHS) cohort. Diet was collected with a 136-item semi-quantitative food-frequency questionnaire. The CQI (range 4-15) was based on: dietary fiber intake, a low glycemic index, the ratio of whole grains/total grains, and the ratio of solid carbohydrates/total carbohydrates. The higher the CQI, the healthier the diet. The MetS was defined by using the harmonized National Cholesterol Education Programme-Adult Treatment Panel III (NCEP-ATP III) definition. The associations across 3-point categories of the CQI and the presence of the MetS was examined using logistic regression.

Results: An inverse and significant association between CQI and the MetS was found. Fully adjusted odds ratios (OR) for the MetS risk among participants in the 10-12 point category (second highest CQI category) was 0.64 (95%CI: 0.45-0.94), and in the 13-15 point category (highest category) was 0.52 (95%CI: 0.30-0.88), when compared with the 4-6 point category (lowest category). Participants with 10-12 and 13-15 points in CQI showed a lower risk of hypertriglyceridemia: OR 0.61 (95%CI: 0.46-0.81), and 0.48 (95%CI: 0.32-0.71) respectively.

Conclusions: Among middle-aged men, a higher adherence to a high-quality carbohydrate diet is associated with a lower prevalence of the MetS. Triglyceridemia is the MetS component that contributed the most to this reduced risk.

Keywords: Carbohydrates, Metabolic Syndrome, Triglycerides, Carbohydrate quality index.

INTRODUCTION

The prevalence of the metabolic syndrome (MetS) is on the rise worldwide, becoming a public health concern (1). The MetS is a condition that includes a cluster of risk factors, such as high waist circumference, high blood pressure, atherogenic dyslipidemia, and high plasma glucose. The MetS has been linked to the development of type II diabetes mellitus and cardiovascular diseases (CVD) (2,3). The increase in the occurrence of the MetS has been attributed to the rise in obesity, which in turn is associated with a sedentary lifestyle (1) as well as with poor dietary habits (4,5). Therefore, efforts to prevent the MetS in the public health arena have been focused on promoting healthy lifestyles, including a healthy diet (2,6).

A high-quality carbohydrate diet is now considered to be healthy and favorable. Thus, improving the quality of carbohydrate intake seems to be more beneficial than reducing their quantity (7). Carbohydrate quality is a multidimensional entity that integrates several parameters and, as such, these parameters could act in a synergetic way (7,8). Traditionally, there are some dietary parameters that were used to assess carbohydrate quality, such as fiber intake, whole grain consumption, the glycemic index (GI), or the glycemic load. It has been shown that a higher intake of fiber and whole-grain is associated with a lower risk of the MetS (9–11), while the consumption of refined grain is positively associated with the MetS (11). In the same way, a high dietary GI increases the risk of the MetS (12,13).

In recent years, authors have assessed the overall carbohydrate quality within a dietary pattern by elaborating a single index, known as the carbohydrate quality index (CQI). The first definition of the CQI was performed by Zazpe et al.(14) allowing scientists to compare participants with different quality and quantity of carbohydrate intake, as well as to describe the role of carbohydrates as a group in disease development. High scores in this index are associated with lower cardio-metabolic risk factors, such as obesity (15,16), high waist circumference (17), high glycated hemoglobin A1c (18), and hypertension (15), which eventually could result in the occurrence of the MetS. High CQI scores have also been associated with lower subclinical atherosclerosis (19), and CVD (20). Nevertheless, the scarce evidence about the association between the CQI and the occurrence of the MetS have shown mixed results(15,21). Therefore, we aim to study the association between the adherence to the CQI and the occurrence of the MetS in a well-characterized Spanish sample of working adults.

MATERIALS AND METHODS

Study design and population

This is a cross-sectional study carried out with a subsample from the Aragon Workers' Health Study (AWHS), whose design and methodology have been previously described (22). The AWHS is a prospective cohort with the aim to characterize risk factors for metabolic abnormalities and subclinical atherosclerosis, by performing annual physical examinations of 5,678 workers belonging to an automobile assembly plant from Spain. Between 2011 and 2014, a total of 2,617 participants aged 39-59 and free from CVD at baseline, who attended extended examinations which included an interview with questionnaires on diet and lifestyles. We excluded women due to their small number (n=132), and those with missing data on diet or on the components of the MetS (n=169). The final sample comprised 2,316 men (Supplemental Figure 1) (23). The study was approved by the Clinical Research Ethics Committee of Aragon (CEICA). All participants provided written informed consent.

Data collection

Diet assessment and carbohydrate quality index (CQI) calculation

The habitual diet over the year preceding the interview was assessed using a semi-quantitative food frequency questionnaire (FFQ) previously validated in Spain (24). This questionnaire collects data on the frequency of the consumption of 136 food items, considering nine frequencies from “never or almost never” to “more than six times a day”. Additionally, dietary energy, macronutrient, and micronutrient intake were derived by using Spanish food composition tables (25,26).

We calculated the CQI (19) to assess an overall index for carbohydrate quality, considering the following components: 1) dietary fiber intake (g/d); 2) the GI; 3) whole grain/total grain ratio; 4) and solid carbohydrate/total carbohydrate ratio. Dietary fiber intake was calculated according to the Spanish food composition tables. GI was calculated as a weighted GI which was based on the GI for each individual food that was obtained from Spanish food composition tables (25,26), and using a previously defined formula (15). Whole-grain consumption was estimated as the sum of ‘whole bread consumption’, ‘integral cereal consumption’, and ‘whole wheat cookie consumption’. Total grain intake was calculated by summing up all types of grains, defined as the intake of whole grains, refined grains, and their products (including refined bread, refined breakfast cereal, white rice, refined pasta, pizza and different biscuits, as well as pastry products). Liquid carbohydrates were calculated by summing up carbohydrates ingested from sugar-sweetened beverages and fruit juice. Solid carbohydrates accounted for the carbohydrate content from the rest of the foods.

Each component contributed to the score as follows (27): 1) For dietary fiber intake, participants were categorized into quartiles, and points were assigned from 1 to 4. Higher fiber intake increases the final score. 2) For GI, participants were categorized into quartiles, but points were assigned in reverse, from 4 to 1. Lower GI values increase the final score. 3) For the ratio of whole grains/total grains, participants were categorized into three groups. Those with no whole grain consumption received 1 point, and the rest were divided into two equally sized groups and received 2 and 3 points. Thus, this component was categorized into three groups based on the low variability consumption of whole grains in the sample. Higher ratios increase the final score. 4) For the ratio of solid carbohydrate/total carbohydrate, participants were categorized into quartiles, and points were assigned from 1 to 4. Higher ratios increase the final score (Table 1).

Finally, the CQI was constructed by summing up all the component scores (ranging from 4 to 15). We classified participants into four 3-point intervals of this final score. Higher CQI values mean better quality of the carbohydrate consumed (Table 1).

Metabolic syndrome definition

The MetS was diagnosed, according to the modified National Cholesterol Education Program - Adult Treatment Panel III definition (NCEP- ATP III) (2), when participants met at least 3 of the following 5 criteria: elevated waist circumference (≥102 cm), elevated fasting blood glucose (≥100 mg/dL or receiving antidiabetic drugs), elevated blood pressure (systolic blood pressure ≥130 mmHg and/or diastolic blood pressure ≥85 mmHg, or receiving antihypertensive drugs), elevated serum triglycerides (TG) (≥150 mg/dL or being on drug treatment for hypertriglyceridemia), and reduced serum high-density lipoprotein cholesterol (HDL-c) (<40 mg/dL).

Sociodemographic, clinical, and biological data

Age, type of work (blue collar or white collar), physical examination, as well as laboratory data were obtained during the annual medical examination by using standardized procedures.

The physical examination included height, weight, waist circumference, and blood pressure measurements. Medical history, and the current use of medication were also collected. Waist circumference was obtained by using a flexible non-extendible measuring tape (GulicK model 67109) which was verified and revised monthly versus another tape calibrated every 3 years. The measurements were taken in the middle point between the iliac crest and the lowest point of the costal margin on the mid-axillary line in a horizontal plane (parallel to the ground), at the end of a non-forced exhale, with arms relaxed along the body and the legs slightly apart.

Laboratory data were obtained from fasting blood samples (>8h). Total cholesterol, HDL-c, triglycerides, and serum glucose were measured by spectrophotometry (Chemical Analyzer ILAB 650, Instrumentation Laboratory). Low-density lipoprotein cholesterol (LDL-c) was calculated using the Friedewald equation when TG were lower than 400 mg/dl.

Lifestyles were obtained by interview. Participants were categorized as ever-smokers if they were "current-smokers" (they reported having smoked in the last year) or "former-smokers" (they had smoked at least 50 cigarettes in their lifetime, but not in the last year).

We assessed physical activity using the validated Spanish version (28) of the frequency of engaging in physical activity questionnaire, used in the Nurses' Health Study (29) and in the Health Professionals Follow-up Study (30). A metabolic value was assigned to each activity using the Ainsworth's compendium for physical activities (31), and was multiplied by the times the participant reported practicing it. We obtained a value for overall weekly METs-h by summing up all the activities.

Hypertension was defined as having systolic blood pressure ≥140 mmHg, or diastolic blood pressure ≥90 mmHg, or self-reported use of antihypertensive medication (32). Diabetes was defined as fasting plasma ≥126 mg/dl or self-reported treatment with hypoglycemic medication (32). Dyslipidemia was defined as having total cholesterol ≥240 mg/dl, or LDL-c ≥160 mg/dl, or HDL-c <40mg/dl, or self-reported use of lipid-lowering drugs (3).

Statistical methods/Analysis

The CQI were categorized into four groups (4-6, 7-9, 10-12, and 13-15 points) and the association of the MetS was examined by using logistic regression. The models were adjusted for age, type of work, body mass index derived from the weight and height of a person in kg/m^2, smoking status, physical activity (total METs-h/week), hypertension, dyslipidemia, diabetes, total energy intake, protein intake, total fat intake, and alcohol intake. Same analyses were performed for the MetS criteria separately. The R statistical software (ver. 4.1.3) was used, and p values below 0.05 were considered statistically significant.

RESULTS

The sample included 2,316 men with a mean age of 50.9 (SD 3.9). Compared with individuals in the lowest CQI category, participants in the highest CQI category had higher concentrations of HDL-c, lower concentrations of triglycerides, and exerted more physical activity (Table 2).

Concerning diet, participants with higher CQI, consume fewer carbohydrates and trans fatty acids, while consuming more protein, and alcohol than participants with lower CQI. (Table 3).

The prevalence of the MetS among participants was 27.5% (636 cases). The prevalence of the diagnosis criteria were: 32.0% for elevated waist circumference, 37.3% for elevated fasting glucose, 57.1% for elevated blood pressure, 37.8% for elevated TG, and 9.5% for reduced HDL-c.

Our results show a significant inverse association between the adherence to the CQI and the occurrence of the MetS. Compared with participants in the lowest CQI category (4-6 points), those in the highest CQI category (13-15 points) had a lower prevalence of the MetS (23.7% vs 27.5%). The fully adjusted odds ratios (OR) for the MetS among participants with 10-12 points was 0.64 (95% CI: 0.45, 0.94), and among those with 13-15 points was 0.52 (95% CI: 0.30, 0.88), when compared with those in the 4-6 point CQI category, p for trend: <0.001 (Table 4, Figure 1). Participants in both, the 10-12 point category and the 13-15 point category, also showed a lower risk of hypertriglyceridemia: OR 0.61 (95%CI: 0.46-0.81), and 0.48 (95%CI: 0.32-0.71) respectively, when compared with those in the 4-6 point category, p for trend: <0.001 (Table 4, Figure 2). No significant association was found for the rest of the MetS components (Table 4).

DISCUSSION

In this large epidemiological study, we found an inverse association between the adherence to the CQI and the occurrence of the MetS. Therefore, consuming a diet rich in high-quality carbohydrates is associated with a lower risk of the MetS among middle-aged Mediterranean working men who were free of CVD. This association was mainly driven by the hypertriglyceridemia component. These findings support that the quality of dietary carbohydrates is likely to play an important role in cardio-metabolic health.

In the latest research, the isolated CQI components showed significant clinical benefits in reducing the risk of the MetS. More in particular, a study performed with 1,301 adult cancer survivors (9) showed that as fiber intake increases the risk of the MetS decreases (9). Moreover, a meta-analysis conducted with fourteen observational studies, both cross-sectional and cohort studies (11), suggested that whole grain consumption was negatively associated with the MetS, whereas refined grain consumption was positively associated (11). Likewise, a meta-analysis that assessed whether a high GI or glycemic load contributed to the development of the MetS (12), showed that a high versus a low dietary GI (but not glycemic load), was associated with an increased risk of the MetS. Finally, the consumption of sugar sweetened beverages, as an example of liquid carbohydrates, are suggested to increase the risk of the MetS. In fact, meta-analyses by Malik et al. (33), and Narain et al. (34), reported that the consumption of sugar sweetened beverages was associated with an increment of 20% and 46% in the risk of developing the MetS, respectively. This may be plausible because liquid form carbohydrates, as in sugar sweetened beverages are suggested to produce less satiety than an equivalent amount of carbohydrates coming from solid food (35).

The association between CQI and the MetS may stem from quality aspects of dietary carbohydrates on traditional metabolic risk factors. For example, two studies performed with adults from Korea (15) and Spain (36), showed a significant inverse association between CQI and the incidence of overweight/obesity (15,36), as well as with hypertension (15). However, another study conducted in the Framingham Offspring cohort (17) showed that a higher CQI was only marginally associated with a small increase in waist circumference, suggesting that CQI does not strongly influence waist circumference. These results are in accordance with the PREDIMED-Plus randomized trial by Martinez-Gonzalez et al.(7), which was conducted among participants at a high risk for CVD. After 12 months of follow-up, improvements in CQI were favorably associated with CVD as well as with improvements in the MetS components. Thus, improvements in CQI lead to a reduction in body weight, waist circumference, systolic and diastolic blood pressure, fasting blood glucose, glycated hemoglobin (HbA1c), triglycerides, and to increments in HDL-c (7), even among those who already had the MetS.

The association between the adherence to the CQI and the MetS has also been previously assessed in a representative sample comprised of 12.027 adults from Korea (15). The association did not reach statistical significance when comparing extreme sex-specific quintiles of the CQI after adjustment for confounders, although central estimates were always protective. In a recent study conducted with 850 participants living in Iran and collected through the health system (21), no association between CQI and the MetS was found after using a modified version of the CQI. Discrepancy in results may stem from differences in the MetS definition (e.g., cut-off points for abdominal obesity were modified in Korean adults to account for their phenotype), also differences among countries in food consumption (e.g., in the Iranian sample no consumption of whole grain was accounted for, which made the investigators eliminate this component from the index), the selection of the samples (e.g., our sample was made up of men), or the few number of events.

The biological mechanisms underlying the association between carbohydrate quality and the MetS could be related to insulin resistance, impaired glucose metabolism, increased inflammation, weight gain and obesity, and reduced fiber intake.

Low-quality carbohydrate diets are practically based on high amounts of carbohydrate from refined sources, such as liquid carbohydrates, white bread, white rice, refined flours, and a high amount of added sugars (37). These diets show a lower consumption of proteins and fats, which are associated with an adverse impact on total mortality (37). A high consumption of refined carbohydrates is usually accompanied by a high dietary GI and glycemic load content (21,37).

Refined carbohydrates, especially those with a high GI, increases digestion and absorption of food, leading to rapid spikes in blood sugar levels, causing an overproduction of insulin and a suppression of free fatty acid levels (38). A counterregulatory hormone response is trigger, reducing reactive hypoglycemia and enhancing the secretion of free fatty acid to levels above those observed after consumption of low GI meal (38,39). Moreover, low quality carbohydrates are characterized by their low dietary fiber content, making satiety signals in the body less effective (40). Over time, the abrupt changes in circulating concentrations of glucose and free fatty acids, that trigger failures in satiety perception, could increase food intake and decrease insulin sensitivity, leading to inflammation, obesity, dyslipidemia, hypertriglyceridemia, and insulin resistance (41,42). Moreover, a low-quality carbohydrate diet is characterized by a high consumption of liquid carbohydrates. Beverages with carbohydrates are easily digestible, providing less satiety signals to the body, but considerably increasing daily caloric intake, promoting the previous mechanisms (43,44).

Our findings extend the knowledge of the benefits of a high-quality carbohydrate diet on the occurrence of the MetS. Our findings are relevant from a public health point of view, since dietary recommendations should include improving the quality of dietary carbohydrates, rather than only limiting their intake in quantity. Improvements in dietary habits should involve high quality carbohydrate consumption, increments in the consumption of fruit and vegetables, a reduction in the consumption of sugar-sweetened beverages, as well as in the consumption of carbohydrates that are quick and easy to digest, such as liquid carbohydrates, refined grains, or those coming from ultra-processed food. Therefore, it is relevant to communicate to the public the importance of the quality of carbohydrates, over quantity. However, it is also desirable to replicate these analyses in other populations, whether Mediterranean or not, and in longitudinal cohort studies.

Strengths and limitations

Our study has several strengths, such as the use of standardized protocols and high-quality data collection methods to obtain information on the MetS, as well as our relatively large sample size. However, it also has several limitations. First, the cross-sectional design does not allow to establish causality, nor the temporality of the associations. Second, our sample of women was too small to be analyzed separately, and therefore results were obtained only among men. In addition, our sample comprised working men, all of whom worked in the same car assembly plant, as such, the results may not be directly generalized to the general population. Third, although the dietary assessment was conducted using an FFQ and carried out by trained interviewers, we cannot rule out the presence of some degree of misclassification (45). However, the scientific literature supports that the FFQ is a valid tool to evaluate food habits in epidemiological studies (25,46). Fourth, even though we adjusted for the major potential confounders, residual confounding may still persist.

In short, this study provides grounds for specific recommendations on improving dietary carbohydrate quality as the primary prevention of the MetS. CQI could also be used to inform the general public about a poor-quality diet which in turn may result in dietary qualitative changes. CQI could also be useful in monitoring these changes.

CONCLUSION

Our results suggest that there is a protective association between the consumption of high-quality carbohydrates and the presence of the MetS and hypertriglyceridemia among middle-aged men free of CVD.

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Table 1. Components and algorithm used to calculate the carbohydrate quality index (CQI).

Components of carbohydrate quality index	Index range (points) (4-15)	Scores according to the groups of the component (cut-off points)			
Dietary fiber intake (g/d)	1-4	G1 = 1 (0, 20.1]	G2 = 2 (20.1, 24.4]	G3 = 3 (24.4, 29.3]	G4 = 4 (29.3, max)
Glycemic index	1-4	G1 = 4 (0, 48.8]	G2 = 3 (48.8, 51.9]	G3 = 2 (51.9, 54.0]	G4 = 1 (54.0, max)
Ratio of whole grains/total grains	1-3	G1 = 1 0	G2 = 2 (0, 0.246]		G3 = 3 (0.246, max)
Ratio of solid carbohydrates/total carbohydrates	1-4	G1 = 1 (0, 0.947]	G2 = 2 (0.947, 0.977]	G3 = 3 (0.977, 0.996]	G4 = 4 (0.996, max)

G=Group; Max= Maximum

Table 2. Baseline characteristics of the AWHS participants according to the carbohydrate quality index (CQI) categories.

		Carbohydrate Quality Index				
		4-6 points (Lowest quality)	7-9 points	10-12 points	13-15 points (Highest quality)	
N = 2,316	**Mean**	n= 334	n= 1,039	n= 745	n= 198	*p* for trend
Age, years	50.9 (3.9)	50.4 (4.2)	51.0 (3.9)	51.1 (3.8)	51.0 (3.6)	0.058
Type of work, *white collar* %[n]	12.0 [277]	10.8 [36]	10.3 [107]	14.4 [107]	13.6 [27]	0.028
BMI, kg/m^2	27.9 (3.5)	27.6 (3.6)	27.9 (3.5)	28.0 (3.4)	27.9 (3.5)	0.292
Waist circumference, cm	98.0 (9.3)	97.5 (9.2)	98.4 (9.3)	97.9 (9.4)	97.2 (8.9)	0.623
Systolic blood pressure, mm Hg	125.6 (14.0)	125.1 (13.9)	126.0 (13.7)	124.9 (14.2)	126.3 (15.3)	0.980
Diastolic blood pressure, mm Hg	82.7 (9.5)	82.8 (9.5)	83.0 (9.2)	82.3 (9.6)	83.0 (10.1)	0.570
Total cholesterol, mg/dl	220.1 (36.3)	220.1 (39.3)	218.7 (34.6)	222.1 (36.5)	219.7 (38.2)	0.351
HDL-c, mg/dl	52.8 (11.4)	51.7 (10.7)	51.7 (10.9)	54.5 (11.8)	54.6 (12.1)	<0.001
Non-HDL-c, mg/dl	167.2 (35.0)	168.4 (38.2)	167.0 (33.3)	167.6 (35.4)	165.1 (37.4)	0.511
LDL-c, mg/dl	137.9 (31.4)	137.4 (34.2)	137.2 (30.6)	138.8 (30.7)	139.3 (33.4)	0.285
Triglycerides, mg/dl	151.8 (98.9)	157.1 (91.0)	155.7 (108.1)	146.8 (88.6)	140.9 (97.5)	0.013
Fasting glucose, mg/dl	98.0 (17.8)	96.7 (16.1)	97.9 (18.7)	98.2 (16.9)	99.4 (18.9)	0.094
Ever-smokers, %[n]	76.7 [1,776]	78.4 [262]	77.9 [809]	74.5 [555]	75.8 [150]	0.126
Physical activity, *total METs-h/week*	32.3 (23.0)	27.6 (20.8)	31.8 (22.2)	34.9 (24.5)	33.4 (23.9)	<0.001
Hypertension, %[n]	38.7 [896]	36.2 [121]	39.0 [405]	38.5 [287]	41.9 [83]	0.308
Dyslipidemia, %[n]	49.4 [1,145]	49.7 [166]	48.7 [506]	49.5 [369]	52.5 [104]	0.546
Diabetes, %[n]	5.8 [135]	4.5 [15]	6.0 [62]	5.5 [41]	8.6 [17]	0.167

BMI: body mass index; HDL-c: High-density lipoprotein cholesterol; Non-HDL-c: non-High-density lipoprotein cholesterol; LDL-c: Low-density lipoprotein cholesterol.
Values are mean (standard deviation) or % [number]. P value for trend from unadjusted regression models.

Table 3 Nutritional baseline characteristics of the AWHS participants according to the CQI categories.

		Carbohydrate Quality Index				
		4-6 points (Lowest quality)	7-9 points	10-12 points	13-15 points (Highest quality)	
N = 2,316	Overall	n= 334	n= 1,039	n= 745	n= 198	*p* for trend
Total energy, ***kcal/day***	2915.1 (731.3)	2814.5 (618.9)	2973.8 (738.2)	2909.1 (775.2)	2799.9 (669.5)	0.570
Carbohydrates, *gr/day*	333.0 (107.3)	334.2 (90.2)	344.3 (111.0)	324.9 (110.9)	302.3 (90.6)	<0.001
Protein, *gr/day*	108.5 (25.4)	101.2 (21.8)	109.0 (25.7)	110.2 (25.8)	112.2 (25.8)	<0.001
Total fat, *gr/day*	111.2 (29.0)	106.1 (24.8)	112.5 (29.2)	112.0 (30.4)	110.1 (28.5)	0.116
Monounsaturated fatty acids, *gr/day*	50.8 (13.7)	48.4 (11.3)	51.4 (13.8)	51.5 (14.4)	49.4 (13.9)	0.17
Polyunsaturated fatty acids, *gr/day*	18.4 (6.7)	17.6 (6.3)	18.8 (6.7)	18.3 (6.8)	18.6 (6.5)	0.363
Satured fatty acids, *gr/day*	32.5 (10.8)	31.9 (9.5)	33.1 (10.8)	32.3 (11.2)	31.2 (10.8)	0.247
Trans-saturated fatty acids, *gr/day*	0.9 (0.5)	0.9 (0.4)	0.9 (0.5)	0.8 (0.5)	0.7 (0.5)	<0.001
Alcohol intake, *gr/day*	21.2 (19.8)	16.8 (17.6)	21.2 (19.1)	23.0 (21.3)	21.6 (20.4)	<0.001
Dietary fiber, *gr/day*	25.5 (8.0)	19.4 (4.0)	23.9 (6.7)	28.2 (7.9)	34.2 (8.3)	<0.001
Glycemic index	50.8 (4.7)	54.2 (2.0)	52.1 (3.5)	48.8 (4.9)	45.5 (4.5)	<0.001
Solid carbohydrates, *gr/day*	320.6 (103.9)	308.6 (84.2)	331.0 (107.5)	316.8 (108.8)	299.8 (89.7)	0.091
Liquid carbohydrates, *gr/day*	12.4 (15.8)	25.6 (20.7)	13.2 (14.8)	8.1 (12.2)	2.5 (3.9)	<0.001
Whole grains, *gr/day*	28.5 (61.6)	0.6 (4.8)	6.9 (29.6)	44.9 (66.7)	127.3 (92.1)	<0.001
Total grains, *gr/day*	282.6 (137.2)	284.0 (119.5)	298.1 (142.1)	268.8 (138.2)	251.4 (124.8)	<0.001

Values are mean (standard deviation) or % [number]. P value for trend from unadjusted regression models.

Table 4 Association between the CQI and the metabolic syndrome, as well as the metabolic syndrome criteria in the AWHS participants.

	Carbohydrate Quality Index				
	4-6 points (Lowest quality) OR (95%CI)	**7-9 points** OR (95%CI)	**10-12 points** OR (95%CI)	**13-15 points** (Highest quality) OR (95%CI)	
Participants (N =2,316)	n= 334	n= 1,039	n= 745	n= 198	*p* for trend*
MetS diagnosis, % (n)	*27.5% (n=92)*	*30.0% (n=312)*	*24.8% (n=185)*	*23.7% (n=47)*	
Age-adjusted	Ref.	1.08 (0.82, 1.43)	0.83 (0.62, 1.11)	0.78 (0.52, 1.17)	0.0384
Multivariable-adjusted†	Ref.	1.00 (0.71, 1.41)	0.64 (0.45, 0.94)	0.52 (0.30, 0.88)	<0.001
Waist circumference criterion for the MetS, % (n)	*30.5% (n=102)*	*33.6% (n=349)*	*31.0% (n=231)*	*29.8% (n=59)*	
Age-adjusted	Ref.	1.12 (0.855, 1.46)	0.99 (0.745, 1.31)	0.94 (0.63, 1.37)	0.624
Multivariable-adjusted†	Ref.	0.98 (0.655, 1.47)	0.73 (0.477, 1.13)	0.72 (0.40, 1.31)	0.0556
Fasting blood glucose criterion for the MetS, % (n)	*35.6% (n=119)*	*37.0% (n=384)*	*37.7% (n=281)*	*40.4% (n=80)*	
Age-adjusted	Ref.	1.01 (0.782, 1.32)	1.04 (0.796, 1.37)	1.18 (0.82, 1.70)	0.239
Multivariable-adjusted†	Ref.	0.96 (0.073 1.28)	0.96 (0.071, 1.29)	1.03 (0.07, 1.54)	0.918
Blood pressure criterion for the MetS, % (n)	*56.0% (n=187)*	*58.4% (n=607)*	*56.0% (n=417)*	*56.1% (n=111)*	
Age-adjusted	Ref.	1.04 (0.807, 1.34)	0.93 (0.714, 1.22)	0.94 (0.66, 1.35)	0.384
Multivariable-adjusted†	Ref.	1.01 (0.715, 1.43)	0.83 (0.573, 1.20)	0.71 (0.41, 1.19)	0.0416
Triglyceride criterion for the MetS, % (n)	*42.8% (n=143)*	*39.9% (n=415)*	*34.4% (n=256)*	*30.8% (n=61)*	
Age-adjusted	Ref.	0.88 (0.68, 1.13)	0.69 (0.53, 0.90)	0.59 (0.40, 0.85)	<0.001
Multivariable-adjusted†	Ref.	0.81 (0.62, 1.06)	0.61 (0.46, 0.81)	0.48 (0.32, 0.71)	<0.001
HDL-cholesterol criterion for the MetS, % (n)	*9.3% (n=31)*	*11.5% (n=120)*	*7.0% (n=52)*	*8.6% (n=17)*	
Age-adjusted	Ref.	1.273 (0.85, 1.96)	0.73 (0.46, 1.18)	0.92 (0.48, 1.68)	0.0215
Multivariable-adjusted†	Ref.	1.538 (0.98, 2.47)	0.88 (0.53, 1.48)	0.95 (0.47, 1.88)	0.0376

OR, odds ratio; CI, confidence interval; N, total number of participants.
†Adjusted for age, type of work (blue collar or white collar), body mass index, smoking status (ever smoker or never smoker), physical activity (total METs-h/week), hypertension, dyslipidemia, diabetes, total energy, protein intake, total fat intake, and alcohol intake.
**P* for trend is calculated using CQI as a continuous variable.

FIGURE LEGENDS

Figure 1 Odds Ratios (95% Confidence Interval) for metabolic syndrome according to carbohydrate quality index categories. OR, odds ratio. Adjusted for age, type of work (blue collar or white collar), body mass index, smoking status (ever smoker or never smoker), physical activity (total METs-h/week), hypertension, dyslipidemia, diabetes, total energy, protein intake, total fat intake, and alcohol intake.

Figure 2 Odds Ratios (95% Confidence Interval) for the triglyceride criterion of the MetS according to carbohydrate quality index categories. OR, odds ratio. Adjusted for age, type of work (blue collar or white collar), body mass index, smoking status (ever smoker or never smoker), physical activity (total METs-h/week), hypertension, dyslipidemia, diabetes, total energy, protein intake, total fat intake, and alcohol intake.

Figure 1

Figure 1 Odds Ratios (95% Confidence Interval) for metabolic syndrome according to carbohydrate quality index categories.

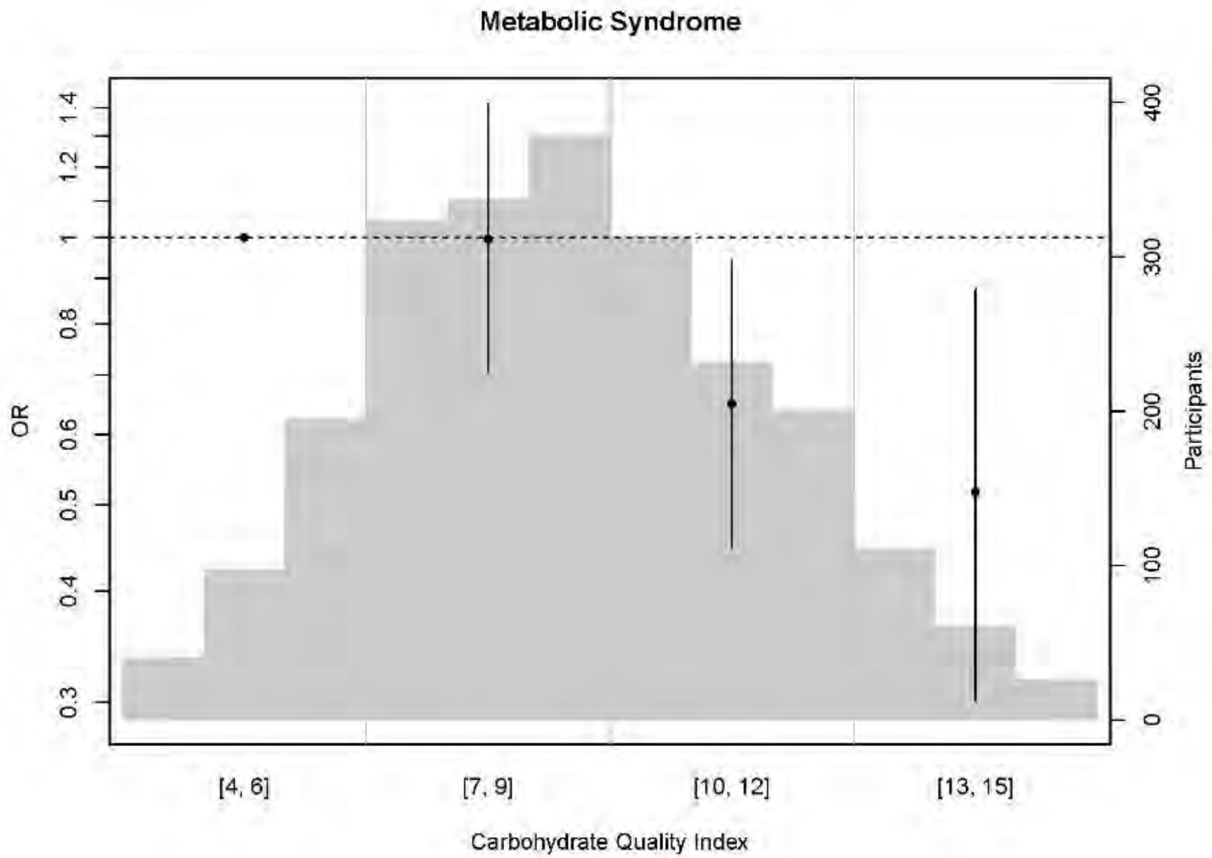

Figure 2

Click here to access/download;Figure;renamed_c473d.pdf

Figure 2 Odds Ratios (95% Confidence Interval) for the triglyceride criterion of the MetS according to carbohydrate quality index categories.