Dietary Intake Relative to Cardiovascular Disease Risk Factors in Individuals With Chronic Spinal Cord Injury: A Pilot Study

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Background: The relationship between cardiovascular disease (CVD) risk factors and dietary intake is unknown among individuals with spinal cord injury (SCI). **Objective**: To investigate the relationship between consumption of selected food groups (dairy, whole grains, fruits, vegetables, and meat) and CVD risk factors in individuals with chronic SCI. **Methods**: A cross-sectional substudy of individuals with SCI to assess CVD risk factors and dietary intake in comparison with age-, gender-, and race-matched able-bodied individuals enrolled in the Coronary Artery Risk Development in Young Adults (CARDIA) study. Dietary history, blood pressure, waist circumference (WC), fasting blood glucose, high-sensitivity C-reactive protein (hs-CRP), lipids, glucose, and insulin data were collected from 100 SCI participants who were 38 to 55 years old with SCI >1 year and compared to 100 matched control participants from the CARDIA study. **Results:** Statistically significant differences between SCI and CARDIA participants were identified in WC (39.2 vs 36.2 in.; *P* < .001) and high-density lipoprotein cholesterol (HDL-C; 39.2 vs 47.5 mg/dL; *P* < .001). Blood pressure, total cholesterol, triglycerides, glucose, insulin, and hs-CRP were similar between SCI and CARDIA participants. No significant relation between CVD risk factors and selected food groups was seen in the SCI participants. **Conclusions:** SCI participants had adverse WC and HDL-C compared to controls. This study did not identify a relationship between consumption of selected food groups and CVD risk factors. **Key words:** *cardiovascular disease risk factors, dietary intake, spinal cord injury*

Cardiovascular disease (CVD) is a leading cause of death in individuals with chronic spinal cord injuries (SCIs).[1-5] This is partly because SCI is associated with several metabolic CVD risk factors, including dyslipidemia,[6-10] glucose intolerance,[6,11-14] and diabetes.[15-17] In addition, persons with SCI exhibit elevated markers of inflammation[18,19] and endothelial activation[20] that are correlated with higher CVD prevalence.[21-23] Obesity, and specifically central obesity, another CVD risk factor,[24-26] is also common in this population.[12,27-29]

Dietary patterns with higher amounts of whole grains and fiber have been shown to improve lipid abnormalities,[30] glucose intolerance, diabetes mellitus,[31-34] hypertension,[35] and markers of inflammation[36] in the general population. These dietary patterns are also associated with lower levels of adiposity.[31] Ludwig et al reported that the strong inverse associations between dietary fiber and multiple CVD risk factors – excessive weight gain, central adiposity, elevated blood pressure, hypertriglyceridemia, low high-density lipoprotein cholesterol (HDL-C), high low-

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density lipoprotein cholesterol (LDL-C), and high fibrinogen – were mediated, at least in part, by insulin levels.[37] Whole-grain food intake is also inversely associated with fasting insulin, insulin resistance, and the development of type 2 diabetes.[32,38,39]

Studies in the general population have also shown a positive association between the development of metabolic syndrome as well as heart disease and consumption of a Western diet, a diet characterized by high intake of processed and red meat and low intake of fruit, vegetables, whole grains, and dairy.[40,41] Red meat, which is high in saturated fat, has been shown to have an association with adverse levels of cholesterol and blood pressure and the development of obesity, metabolic syndrome, and diabetes.[40,42,43]

Numerous studies have shown that individuals with chronic SCI have poor diet quality.[44-49] A Canadian study found that only 26.7% of their sample was adherent to the recommendations about the consumption of fruit, vegetables, and grains from the "Eating Well with Canada's Food Guide."[44] Individuals with chronic SCI have also been found to have low fiber and high fat intakes when their diets were compared to dietary recommendations from the National Cholesterol Education Program,[46] the 2000 Dietary Guidelines for Americans,[49] and the recommended Dietary Reference Intakes and the Acceptable Macronutrient Distribution Range.[47,48]

However, unlike in the general population, the relationship between dietary intake and obesity and CVD risk factors is unknown in the chronic SCI population. If a dietary pattern consisting of higher intake of whole grains and dietary fiber is favorably associated with obesity and CVD risk factors in individuals with chronic SCI, then trials of increased intake of whole grains and fiber intake could be conducted to document health benefits and inform recommendations. The purpose of this pilot study is to investigate the association between selected food group intake and CVD risk factors in individuals with chronic SCI as compared to age-, gender-, and race-matched able-bodied individuals enrolled in the Coronary Artery Risk Development in Young Adults (CARDIA) study. Data will also be used to plan future studies in the relatively understudied field of CVD and nutrition in individuals with SCI.

Methods

CARDIA population

CARDIA is a multicenter, population-based, prospective study of CVD risk factor evolution in 5,115 African American and non-Hispanic White men and women ages 18 to 30 years at baseline (1985–1986) who were recruited from 4 US field centers: Birmingham, Alabama; Chicago, Illinois; Minneapolis, Minnesota; and Oakland, California. To date, there have been 8 clinical exams at years 0, 2, 5, 7, 10, 15, 20, and 25. At baseline, participants could not have any long-term disease or disability that would significantly interfere with any part of the examination. Participants were excluded if they were severely visually or hearing impaired, mute, intellectually disabled, or unable to walk on a treadmill unassisted. They also could not be pregnant or less than 3 months postpartum. Details of this study have been previously described.[50] Randomly selected CARDIA participants were frequency matched to SCI individuals by 5-year age range, race, and sex at the year 20 CARDIA exam (data were collected in 2005-2006). Seventy-two percent of the surviving cohort attended the year 20 exam. None of these participants had an SCI or other significant disability. This population was selected because of its size and its broad representation of the US population, making it more generalizable. Its established database and validated measures increased the feasibility of the study.

SCI participants

One hundred and thirty-four SCI participants with chronic SCI (>1 year) presenting to a single site for dietary intake and CVD risk assessment were enrolled in this study. They were age- (±5 years), gender-, and race-matched to able-bodied individuals from the CARDIA study population. In accordance with the CARDIA race and gender inclusion criteria and the age range of participants at the time of their year 20 follow-up exam, participants were men and women of African American or non-Hispanic White race between the ages of 38 and 50 (±5 years). For inclusion, SCI participants must have had sustained a nonvascular insult that caused an acute SCI (ie, traumatic injury, transverse myelitis without a diagnosis of multiple sclerosis, surgical complication, or benign neoplasm) at least 1 year prior to enrollment in the study. In addition, study participants must have had an American Spinal Injury Association Impairment Scale (AIS) classification of A, B, or C[51] and adequate English communication skills to complete the surveys. Exclusion criteria included AIS D classification, pregnancy, end-stage renal disease, treatment for cancer except for nonmelanoma skin cancer within the past 5 years, and chronic nontobacco substance abuse.

Participants who had previously given consent to be in an ongoing SCI registry were recruited via letters sent to their home address. Other participants were recruited with the assistance of their rehabilitation physician during visits to the outpatient rehabilitation clinic. All participants provided informed written consent. The consent form and the entire study were approved by the local institutional review board.

Thirty-three individuals withdrew from the study or were lost to follow-up, and one was later excluded due to race/ethnicity. All of these participants withdrew or were excluded prior to any data collection of CVD risk factor measurements or dietary intake. Three of these participants took their consents home to complete, but they did not return them or respond to further communication. Their demographic information was not retained. Therefore, 100 SCI participants were included in the final analysis. Demographic characteristics for the 100 SCI study participants and age-, sex-, and race-matched CARDIA participants are described in **Table 1**.

Table 1. Descriptive characteristics of spinal cord injury participants (SCI) and CARDIA study participants

Characteristics	SCI	CARDIA
No. of participants	100	100
Mean age (*SD*)	45.3 (5.1)	44.8 (4.4)
Male	78	78
Female	22	22
Non-Hispanic Whites	66	66
African Americans	34	34
Tetraplegia	57	N/A
Paraplegia	43	N/A
AIS classification		N/A
A	66	
B	16	
C	18	
Time since injury, years (*SD*)	15.1 (9.6)	N/A

Note: AIS = American Spinal Injury Association Impairment Scale; CARDIA = Coronary Artery Risk Development in Young Adults; N/A = not applicable.

Dietary intake

The CARDIA Dietary History was used to assess dietary intake in both CARDIA and SCI participants. The CARDIA Dietary History is a comprehensive, quantitative food frequency assessment method.[52] It was developed to reflect the current food supply, frequently consumed foods of young adults, race-specific preferences, and certain regional foods. There are 100 open-ended food questions used along with food models to facilitate estimation of portion sizes. The dietary history was validated in CARDIA-like adults,[53] but not in individuals with SCI. To ensure that all foods consumed were queried, the last question was open-ended regarding intake of any other foods not previously reported. Food groups were created including dairy, fruits and vegetables, and whole-grain products.

Cardiovascular disease risk factor assessment

The cardiovascular risk factor assessment consisted of biological samples, measures of adiposity, and measurement of blood pressure. Venous blood samples were taken after an overnight fast (at least 8 hours). Assays included a plasma lipid panel and serum values of glucose, insulin, and high-sensitivity C-reactive protein (hs-CRP). Total cholesterol (TC) and triglycerides (TG) were determined using an enzymatic colorimetric test and HDL-C was determined using a homogeneous enzymatic colorimetric test (Beckman Coulter). For participants with TG less than 400 mg/dL, LDL-C values were calculated using the Friedewald equation.[54]

Waist circumference (WC) was assessed as a measure of central adiposity for both SCI and able-bodied individuals. WC has been shown to represent visceral adipose tissue in individuals with SCI.[29] WC was obtained in a supine position because standing measurement is not feasible in individuals with SCI.[55] CARDIA participants had their WC assessed while standing. Recumbent and standing measures of WC are highly comparable.[56] In the CARDIA study, WC was measured laterally at the point midway between the iliac crest and the lowest lateral portion of the rib cage and anteriorly at the point midway between the xiphoid process of the sternum and the umbilicus.[55] This same technique was used to measure WC in our study. There were 22 participants who were unwilling to be transferred and could not be placed in a supine position in their wheelchair, and therefore they were not included in the analysis.

Physical activity assessment

Physical activity levels were assessed in each participant to adjust for physical activity as a confounding factor on CVD risk factors and measures of adiposity. The Physical Activity Scale for Individuals with Physical Disabilities (PASIPD) was used for this assessment in the SCI participants. This is a 13-item scale that quantifies different levels of physical activity (leisure, household, and work) performed over the previous week. The measure has been shown to have validity in SCI.[57] The CARDIA participants' physical activity was assessed using the Physical Activity History score.[58]

Data analysis

SAS version 9.2 (SAS Institute, Cary, NC) was used for all data analysis. Participant characteristics of each group were described using means (*SD*) and frequencies (%) (**Table 1**). Because of substantial right skewing, insulin and TG were natural-logarithmically transformed to normalize the distribution for comparison between categories in **Table 2.** Linear regression models were used to determine the mean (*SD*) CVD risk factors between SCI and CARDIA participants (**Table 2**). Further, in similar analysis, mean (standard error) was reported for number of servings for each food group consumed stratified by SCI and CARDIA group, adjusting for energy intake. A third linear regression analysis was conducted to evaluate the relations of CVD risk factors, including WC, systolic and diastolic blood pressure, TC, HDL-C, LDL-C, TG, glucose, and insulin, with servings of each major food group among age-, sex-, and race-matched SCI and CARDIA participants, adjusting for education, center, and physical activity (**Table 3**). Because the physical activity scales were different for each group, the SCI and CARDIA participants were arbitrarily divided by their respective physical activity scores into tertiles to capture low, medium, and high levels of physical activity and to homogenize extreme values into a uniform low or high category. Effect modification by group status was suspected, therefore, an interaction term (Group Status x Food Group) was entered into the model. Separate linear regression models that were further examined for each study group the relation between CVD risk factors and servings of major food groups (**Table 3**). Statistical significance was based on 2-sided tests with a type 1 error $P < .05$.

To compute the sample sizes that would be required for future studies, we used the means and standard deviations from our results in this article. These were entered into SAS Proc Power, and we chose a power of 80% and $\alpha = 0.05$. The SAS package uses the standard formulas for deriving sample size for *t* tests using the information as above to compute the sample size required for each of the 2 groups.

Results

Demographic characteristics for SCI participants and the age-, sex-, and race-matched CARDIA participants are described in **Table 1**. The SCI group had a statistically significantly lower mean HDL-C and current smoking prevalence and significantly greater WC than CARDIA participants. Otherwise, there were not any statistically significant differences in CVD risk profiles, but mean values of glucose and insulin were marginally lower in the SCI group compared to the CARDIA group. The SCI group consumed significantly less dairy, fruit,

Table 2. Clinical characteristics and dietary intake for age-, sex-, and race-matched CARDIA and SCI study participants

Characteristics, *M* (*SD*) or *n* (%)	**SCI (*n* = 100)**	**CARDIA (*n* = 100)**	***P***
Current smoking	28.0 (45.1%)	20.0 (40.2%)	.19
BMI, kg/m^2	26.8 (7.2)	27.8 (4.3)	.19
WC	39.2 (6.8)[a]	36.2 (4.5)	<.001
SBP, mm Hg	116.1 (20.1)	116.9 (13.6)	.76
DBP, mm Hg	71.6 (13.7)	71.3 (10.0)	.84
Total cholesterol	181.7 (42.9)	186.0 (37.2)	.45
LDL-C, mg/dL	119.1 (36.6)	115.9 (33.7)	.54
HDL-C, mg/dL	39.2 (10.6)	47.5 (11.3)	<.001
Triglycerides, mg/dL	116.7 (68.4)	120.7 (93.1)	.73
Glucose	93.1 (21.3)[b]	96.7 (13.1)	.15
Insulin	13.3 (13.4)[c]	16.2 (11.9)	.12
hs-CRP (μg/mL)	1.67 (3.1)	1.58 (1.8)	.79
Food intake, *M* (SE) servings/day[d]			
Dairy	2.4 (0.44)	4.9 (0.44)	<.001
Fruit	2.4 (0.39)	3.9 (0.39)	.004
Vegetables	4.5 (0.47)	4.8 (0.47)	.61
Whole grains	1.3 (0.31)	2.2 (0.31)	.02
Meat	5.5 (0.32)	4.2 (0.32)	.002

Note: BMI = body mass index; CARDIA = Coronary Artery Risk Development in Young Adults; DBP = diastolic blood pressure; HDL-C = high-density lipoprotein cholesterol; hs-CRP = high-sensitivity C-reactive protein; LDL-C = low-density lipoprotein cholesterol; SBP = systolic blood pressure; WC = waist circumference.
[a]*n* = 78.
[b]*n*= 95.
[c]*n* = 98.
[d]Adjusted for kcal.

and whole grains and significantly more meat. Vegetable intake was similar (**Table 2**). We further determined the number of those consuming the recommended number of servings from each food group among the SCI participants: 22 consumed ≥3 cups dairy/day, 39 consumed ≥5 cups of fruits and vegetables/day, and 8 participants consumed the recommended ≥3 ounces/day of whole grains.

Finally, we examined the relation between CVD risk factors and major food groups for the SCI and CARDIA participants; however, there were not any statistically significant relations between individual CVD risk factors and food groups in either group (**Table 3**). Effect modification was tested to determine whether the relation between CVD risk factor and food group was different between groups. Effect modification by study group was observed for whole-grain intake and CVD risk factors, systolic blood pressure, diastolic blood pressure, glucose, and hs-CRP, and between fruit and vegetable intake and insulin levels.

Of the 30 participants who gave their consent, but did not complete the dietary or CVD risk factor analysis, the average age was 43.6 years. There were 14 (46.7%) participants with tetraplegia and 16 (53.3%) and with paraplegia. Twenty-seven (90%) were male and 3 (10%) were female.

Discussion

This study did not show a beneficial relationship between particular food groups and individual CVD risk factors for either group. These negative findings may be attributable to the severity of CVD risk factors, especially HDL-C and WC, in individuals with chronic SCI. It is possible that

Table 3. Beta coefficients (SE) of the relation between intake of selected food groups and CVD risk factors for SCI and CARDIA participants

Risk factor	Study group	Vegetables and fruit	Whole grains	Dairy	Meat
WC	SCI	-0.007 (0.14)	0.22 (0.60)	0.43 (0.55)	0.06 (0.31)
	CARDIA	-0.18 (0.08)	-0.05 (0.13)	0.14 (0.08)	0.10 (0.13)
	$p_{interaction}$	.29	.79	.27	.81
SBP, mm Hg	SCI	-0.009 (0.38)	2.26 (1.46)	1.21 (1.45)	0.84 (0.78)
	CARDIA	0.42 (0.26)	-0.31 (0.45)	-0.07 (0.26)	0.42 (0.45)
	$p_{interaction}$	.53	.06	.53	.79
DBP, mm Hg	SCI	0.23 (0.26)	1.51 (0.99)	-1.25 (0.97)	0.23 (0.53)
	CARDIA	0.001 (0.19)	0.13 (0.33)	0.08 (0.19)	-0.03 (0.33)
	$p_{interaction}$	.18	.05	.38	.27
Total cholesterol	SCI	-0.33 (0.83)	0.32 (3.22)	0.70 (3.15)	2.53 (1.68)
	CARDIA	0.17 (0.73)	-0.59 (1.25)	-0.19 (0.73)	0.31 (1.26)
	$p_{interaction}$	.40	.79	.96	.65
LDL-C, mg/dL	SCI	-0.25 (0.71)	0.45 (2.78)	0.21 (2.72)	2.47 (1.45)
	CARDIA	0.49 (0.67)	-0.38 (1.15)	-0.52 (0.68)	0.12 (1.16)
	$p_{interaction}$	.55	.97	.85	.90
HDL-C, mg/dL	SCI	-0.15 (0.20)	-0.23 (0.79)	0.04 (0.77)	0.43 (0.41)
	CARDIA	-0.018 (0.22)	0.81 (0.36)	-0.24 (0.22)	-0.20 (0.38)
	$p_{interaction}$	.14	.20	.63	.87
Triglycerides, mg/dL	SCI	0.36 (1.33)	0.33 (5.18)	2.15 (5.07)	-1.87 (2.74)
	CARDIA	-1.21 (1.83)	-5.12 (3.11)	2.23 (1.82)	0.48 (3.17)
	$p_{interaction}$	.59	.71	.94	.46
Glucose	SCI	-0.14 (0.41)	5.45 (1.45)	1.47 (1.54)	0.39 (0.84)
	CARDIA	-0.23 (0.25)	-0.05 (0.43)	0.36 (0.25)	0.58 (0.43)
	$p_{interaction}$	.99	.0002	.57	.31
Insulin	SCI	0.29 (0.25)	1.20 (0.97)	-0.08 (0.97)	-0.25 (0.52)
	CARDIA	-0.16 (0.23)	-0.04 (0.40)	0.38 (0.095)	0.16 (0.40)
	$p_{interaction}$	.033	.17	.56	.68
hs-CRP (μg/mL)	SCI	-0.14 (0.06)	0.29 (0.23)	0.17 (0.22)	-0.15 (0.12)
	CARDIA	-0.02 (0.04)	-0.07 (0.06)	0.046 (0.04)	-0.05 (0.06)
	$p_{interaction}$	.78	.022	.14	.27

Note: Adjusted for age, sex, race, center, education, energy intake, and physical activity. Interaction by group status was suspected, therefore, separate linear regression models were run for each group. CARDIA = Coronary Artery Risk Development in Young Adults; CVD = cardiovascular disease; DBP = diastolic blood pressure; HDL-C = high-density lipoprotein cholesterol; hs-CRP = high-sensitivity C-reactive protein; LDL-C = low-density lipoprotein cholesterol; SBP = systolic blood pressure; WC = waist circumference.

dietary intake of certain foods may not be as effective in this population, because of the body composition changes and the relative sedentary lifestyle after SCI and the subsequent associated metabolic consequences. This could be especially true in our sample, because the majority of our sample had tetraplegia (57%) and was mostly motor complete (82%). However, all of the risk factor means other than HDL-C and WC were within normal limits and only a few individuals had elevated risk factors, so it is also possible that there was not a relationship because both groups had relatively healthy numbers.

Small sample size may be another possibility for the negative findings. For example, consumption of dairy, fruits, vegetables, and whole grains individually and as a part of a prudent diet have had beneficial effects on CARDIA participants' blood pressure, metabolic syndrome, insulin, and obesity when the entire cohort was considered.[42,59,60] Our study was designed as a pilot study to examine dietary intake in individuals with chronic SCI and the relation between diet and CVD risk factors in the SCI population and to provide useful information for planning larger, more definitive studies. We used the means and standard deviations from our results from the assessment of relations between selected food groups and CVD risk factors for 2 of the risk factors to calculate how many participants we would have needed to see a statistically significant relation. To show a relation between whole grains and WC, 352 participants per group would be needed. For the relation between fruits and vegetables and LDL-C, 306 participants per group would be needed.

Our SCI participants consumed less whole grains, fruits, vegetables, and dairy than the CARDIA comparisons. However, both the SCI participants and the CARDIA participants consumed somewhat higher average intake of whole grains, fruits, vegetables, and dairy than has been previously reported in the general population. Data from the National Cancer Institute on food intakes in the US population for people 31 to 50 years old from 2001 to 2004 demonstrated the following food intakes: whole grains, 0.7 servings/day; fruit, 1.1 cups/day; vegetables, 1.9 cups/day; and dairy 1.8 cups/day.[61] The SCI participants may be limited in their dietary choices by access to healthy foods or economics.[62] Compared to the CARDIA participants, the SCI participants had significantly lower HDL-C levels and significantly greater TC:HDL-C ratios and WC. This is similar to what has been previously reported.[7,9,28,63,64] The SCI participants did have a significant lower rate of smoking than the CARDIA participants. The 28% smoking rate in the SCI participants is greater than the 19% prevalence in the US general population[65] and is similar to what has been previously reported in this population.[66] Smoking is a significant CVD risk factor,[67,68] and future efforts should be aimed at decreasing the increased prevalence in the SCI population.

The consumption of whole grains, fruits, and vegetables is emphasized for the general population, because of their known benefits for risk of CVD and type 2 diabetes. A 2004 review article of 13 prospective studies of the impact of whole-grain foods on CVD and diabetes in the general population found an inverse association between chronic heart disease, stroke, and CVD incidence and mortality. They found a reduction in risk of atherosclerotic CVD events and diabetes ranging from 20% to 40% with the consumption of whole grains.[69] The consumption of whole grains, fruit, and vegetables has been shown to have a beneficial effect on the risks of total mortality and incident coronary artery disease.[70] Higher intake of fruits and vegetables alone has also been shown to be protective from CVD.[71] Beyond our current study, no other published studies have looked at the relationship between selected food groups or dietary patterns and CVD or CVD risk factors in individuals with chronic SCI, so it is unknown whether these same health benefits occur in this population.

Although this study did not show a statistically significant relationship between dietary intake and CVD risk factors, individuals with chronic SCI should be encouraged to maintain a healthy weight by exercising and following a healthy dietary pattern given the current lack of definitive data in this population and the strong evidence in able-bodied adults about obesity and CVD and overall mortality and the benefits of physical activity and a healthy diet.[24,72-74] The 2010 Dietary Guidelines for Americans describe a healthy diet pattern as one that "limits intake of sodium, solid fats, added sugars, and refined grains and emphasizes nutrient-dense foods and beverages – vegetables, fruits, whole grains, fat-free or low-fat milk and milk products, seafood, lean meats and poultry, eggs, beans and peas, and nuts and seeds."[75(p9)] These guidelines recommend at least 3 servings of dairy, preferably low fat, at least 5 servings of fruit and vegetables per day, and at least 3 1/2 servings of whole grains per day for men who are 31 to 50 years old.[75] Although these recommendations are based upon studies in the general population, they may also apply to persons with chronic SCI. In addition to the potential effects of diet on CVD following SCI, there are effects of poor dietary intake on obesity that may have negative effects on function in SCI.[76] Our data did show that the SCI group had lower prevalence of current smoking and the suggestion of lower glucose and insulin values; however, WC, a marker of central adiposity, was higher and HDL-C was lower in the SCI group compared to the CARDIA participants, reflecting both positive and negative health outcomes.

This study has several limitations worth considering. Power was limited by the relatively small sample size. Additionally, dietary intake was obtained from a questionnaire utilizing the self-report method, and self-reported dietary intake may underestimate actual dietary intake. These are also cross-sectional data, so no causal inferences can be made. Finally, SCI participants were recruited from a convenience sample at a single site in the southeastern United States. As a result, our sample was not representative of the US chronic SCI population.

Conclusions

Individuals with chronic SCI had lower HDL-C and higher WC compared to their age-, gender-, and race-matched controls from the CARDIA population. There was no relation between whole-grain, dairy, fruit and vegetable, and meat food groups and individual CVD risk factors.

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