Associations between food groups, dietary patterns, and cardiorespiratory fitness in the Coronary Artery Risk Development in Young Adults study[1–3]

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ABSTRACT

Background: Few studies have investigated the association between overall diet and cardiorespiratory fitness (CRF).

Objective: We aimed to investigate associations of food groups, a diet-quality score, and dietary patterns with CRF in black and white adults.

Design: We included 2632 participants aged 38–50 y who attended the year 20 exam of the Coronary Artery Risk Development in Young Adults (CARDIA) study and Coronary Artery Risk Development in Young Adults Fitness Study (CFS) conducted in 2005–2006. Diet was assessed by using a validated diet history. A dietary score and 2 types of patterns were included as follows: the a priori diet-quality score and meat and fruit-vegetable dietary patterns derived from principal components analysis. CRF was assessed by using a graded exercise treadmill test. Linear regression models regressed the treadmill duration on food groups and dietary scores and patterns overall and in race-sex subgroups.

Results: Grains (whole and refined), processed meats, and beverages (coffee, meal-replacement drinks, beer, and wine) were positively associated with the treadmill duration overall; whole fruit (not juices), organ meats, fried meats and fish, and soy and nondairy products were negatively associated. The a priori diet-quality score was positively associated with the duration overall and in all race-sex subgroups ($P < 0.05$) except black men. The meat pattern was negatively associated with the duration in white men and white women only. The fruit-vegetable pattern was positively associated with duration in white women only.

Conclusions: Overall, the a priori diet-quality score was positively associated with CRF in this cohort of black and white adults, whereas the meat dietary pattern was negatively associated only in whites. The CARDIA study and CFS were registered at clinicaltrials.gov as NCT00005130 and NCT00106457, respectively. *Am J Clin Nutr* 2013;98:1402–9.

INTRODUCTION

Independent effects of diet and physical activity in the prevention and treatment of cardiovascular disease (CVD)[4] and other disorders have been proposed, if not firmly established (1, 2). The relatively few studies in the literature have shown inconsistent associations between various dietary constituents and physical activity. Far fewer studies have investigated the association between diet and cardiorespiratory fitness (CRF), which is an objective measure of habitual physical activity (3) that also is influenced to a significant degree by other factors, including genetics (4).

Although several studies have investigated associations between specific nutrients (including macronutrients and micronutrients) and CRF (3–10), few studies have investigated the associations between CRF and *1*) the intake of food groups and *2*) overall dietary patterns, which is information that may be more relevant to the actual dietary intake in humans. Data are limited, but in several studies, the intake of fruit and vegetables has shown a positive association with CRF (6, 11, 12).

In line with previous research that has shown that healthier diet patterns are associated with lower CVD risk, we considered that such patterns would be positively associated with CRF as assessed by the duration on a graded exercise treadmill (GXT) test. The Coronary Artery Risk Development in Young Adults (CARDIA) study and its ancillary Coronary Artery Risk Development in Young Adults Fitness Study (CFS) provided an opportunity to further investigate the association between diet and CRF. Comprehensive dietary data were collected during the

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[4] Abbreviations used: CARDIA, Coronary Artery Risk Development in Young Adults; CFS, Coronary Artery Risk Development in Young Adults Fitness Study; CRF, cardiorespiratory fitness; CVD, cardiovascular disease; GXT, graded exercise treadmill; MET, metabolic equivalent task; $\dot{V}O_2$max, maximal oxygen uptake.

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CARDIA year 20 exam by using a diet-history questionnaire, whereas objective data on CRF by using a GXT test were obtained through the CFS at the same exam. In this report, we present associations of food groups, a diet-quality score, and dietary patterns with CRF. We hypothesized that the a priori dietary-quality score and fruit-vegetable dietary pattern would be positively associated with the treadmill duration, whereas the meat pattern would be inversely associated in the overall cohort and 4 race-sex subgroups.

SUBJECTS AND METHODS

Study sample

The CARDIA study is a multicenter, longitudinal investigation of the evolution of coronary heart disease risk starting in young adulthood (13). The CARDIA study was initiated in 1985–1986 with a baseline cohort of 5115 adults aged 18–30 y enrolled from the following 4 metropolitan areas: Birmingham, AL; Chicago, IL; Minneapolis, MN; and Oakland, CA. The original cohort included approximately equal numbers of blacks and whites, men and women, aged 18–24 and 25–30 y, and with a high school education or less or more than a high school education. Follow-up exams included the year 20 exam conducted in 2005–2006, which included 71.8% of the surviving cohort. The study was approved by institutional review boards at each participating institution, and all subjects provided written informed consent.

As an ancillary study to the CARDIA study, the overall goals of the CFS were to assess changes in CRF from young adulthood to middle age and to document how different patterns of change in CRF over a 20-y period were related to changes in CVD risk factors and the development of subclinical CVD endpoints. Among other measures, CFS added CRF, which was assessed by using a symptom-limited GXT test, to the CARDIA year 20 exam by using the same protocol that was used at the CARDIA year 0 exam. Subjects included in the current analysis were CARDIA participants who completed the CARDIA diet history and the CFS GXT test at the year 20 exam (n = 2966). Men with a calculated mean energy intake <800 kcal/d (n = 126) or >8000 kcal/d (n = 19) and women with a calculated mean energy intake <600 kcal/d (n = 174) or >6000 kcal/d (n = 15) were excluded, which resulted in 2632 participants in the analysis.

Dietary assessment and creation of food groups

Diet was assessed at year 20 through an interviewer-administered, validated diet history (14). Interviewers asked questions about dietary consumption in the previous month within 100 food categories to which a positive response would trigger the posing of additional information-gathering questions. For example, a positive response to the question "Do you eat any fast food hamburgers or cheeseburgers?" would trigger the additional questions "What kind do you have?" "How many?" "How often?" Foods were assigned to one of 166 food groups by using the food-grouping system devised by the Nutrition Coordinating Center at the University of Minnesota. Food-group intake was calculated as the total number of servings reported per day of each food within a given food group. Recipes were decomposed into constituent foods, assigned a number of servings per day, and added to the appropriate food group.

TABLE 1
Major (n = 18) and nuanced (n = 46) food groups[1]

Food group	Classification
1) Fruit	
Fruit	B
Fruit juices	N
2) Vegetables, excluding potatoes	
Green leafy	B
Dark yellow	B
Tomatoes	B
Avocados/guacamole	B
Other	B
3) Vegetables, potatoes	
Potatoes	N
Fried potatoes	A
4) Grains	
Whole-grain foods	B
Refined grains	N
Sweet breads	A
Salty snacks	A
Grain desserts	A
5) Meats and fish	
Red meat regular	A
Red meat lean	N
Processed meats	A
Organ meats	A
Poultry	B
Fish	B
Fried (fish, chicken, shellfish)	A
Lean fish	B
Shellfish	N
6) Dairy	
Low fat	B
Whole fat	A
7) Fats	
Margarine	N
Oil	N
Butter	A
8) Beans	B
9) Eggs/omelets	N
10) Seeds, nuts, peanut butter	B
11) Salad dressings/sauces	N
12) Soups	B
13) Soy/nondairy products	B
14) Pickled foods	A
15) Chocolate	N
16) Sweet extras	A
17) Sugar substitutes	N
18) Beverages	
Sugar-sweetened soft drinks	A
Diet soft drinks	N
Coffee	B
Tea	B
Meal-replacement drinks	N
Beer	B
Liquor	B
Wine	B

[1] Forty-six nuanced food groups included subgroups and single-item major food groups (groups 8–17). The a priori diet quality score was created by the investigators, who classified these food groups as B, A, or N in terms of their hypothesized disease relations. A, adverse; B, beneficial; N, neutral.

The 166 Nutrition Coordinating Center food groups were collapsed into 46 food groups, as shown in **Table 1**, to approximate those established for investigating diet and cardiovascular outcomes in previous studies (15, 16). These food groups were created on the basis of considerations of a similar nutrient content, hypothesized biologic effects, and comparability to food groups defined in a previous study (17). To simplify some analyses and results, we further aggregated these nuanced food groups into 18 major food groups, which are also shown in Table 1.

Dietary patterns

We created a diet score and 2 dietary patterns on the basis of the 46 food groups as in previous studies (15, 18–21). The diet-quality score was defined a priori and was created by the investigators by classifying food groups as beneficial (20 groups), adverse (13 groups), or neutral (13 groups) in terms of their hypothesized disease relations. We categorized food groups with purported beneficial or adverse health effects (33 groups) into quintiles of consumption, with participants assigned a score that ranged from 0 to 4 for each of these 33 food groups, depending on their level of consumption. For food groups for which large subsets of participants were nonconsumers, we coded nonconsumers as 0 and divided consumers into quartiles with scores from 1 to 4 to ensure variability across 5 levels of consumption. The a priori diet-quality score was the sum of category scores 0–4 for beneficial food groups plus scores in reverse order (4–0) for adverse food groups. We did not include food groups rated as neutral in the calculation of the a priori diet-quality score. Accordingly, the theoretical maximum a priori diet-quality score was 132.

The 2 dietary patterns were based on results of principal components analysis with orthogonal rotation to derive uncorrelated dietary patterns from the 46 food groups. The 2 principal components that explained the most dietary variance were included in the analysis. These so-called meat and fruit-vegetable dietary patterns reflected their relative high loadings of meat and fruit-vegetables, respectively.

Graded exercise treadmill test

The GXT test at year 20 was designed to assess the maximal, symptom-limited performance by using a modified Balke protocol (22). The prediction of the maximal oxygen uptake ($\dot{V}O_2$max) with the Balke protocol from the treadmill duration has been shown to be high at r = 0.94 (23). The testing procedure included the following components: screening (medical history and physical examination) for medical eligibility, participant preparation for an electrocardiogram, resting (supine) 12-lead electrocardiogram, preexercise (standing) 3-lead electrocardiogram and blood pressure, exercise on the treadmill, and recovery after exercise. Pulse rate, blood pressure, and a 12-lead electrocardiogram were obtained on each participant at rest, and heart rate, blood pressure, and a 3-lead electrocardiogram were obtained at the end of each stage, at maximum exercise, and every minute for 3 min postexercise. The test consisted of up to nine 2-min stages (≤18 min total) of progressively increasing difficulty, with speed increasing from 3.0 mph in stage 1 to 5.6 mph in stage 9 and grade increasing from 2% in stage 1 to 25% in stage 9. The first 6 stages generally could be performed by walking, whereas the final 3 stages required jogging and running. Estimated metabolic equivalent tasks (METs) ranged from 4.1 in stage 1 to 19.1 in stage 9. Total seconds of treadmill exercise were recorded for each participant and used in the current analysis.

Other measures

Information on sex, race, age, education, cigarette smoking, alcohol intake, and physical activity was obtained by using a structured interview or self-administered questionnaire. Educational status was quantified as the maximum reported number of years of schooling completed. Smoking status was classified as never, former, or current smoker. Alcohol consumption in drinks per week was computed from a self-reported frequency of beer, wine, and liquor consumption. Physical activity was self-reported. The physical activity questionnaire recorded how many months in the past year the participant reported doing each of a list of activities and how many months the weekly duration was greater than a specified threshold (eg, 2 h/wk for running and jogging). The physical activity score was calculated as the number of months reported for each activity weighted by intensity (by using a rough estimate of energy expenditure per minute), with increased weight for the number of months with activity greater than the threshold (24). Height and weight were measured at the year 20 exam and recorded to the nearest 0.5 cm and 0.2 kg, respectively. BMI (in kg/m^2) was derived from these measures as weight divided by height squared.

Statistical methods

We divided all continuous covariates into quartiles by using the proc rank procedure (SAS version 9.2; SAS institute Inc), and we examined the resulting frequencies along with cross tabulations by race-sex subgroups and field center. We used linear regression to model the duration of the treadmill test in seconds with the proc GLM procedure (SAS version 9.2). We fit 4 separate models by using the entire cohort regressing the treadmill duration on *1*) 46 nuanced food groups, *2*) 18 major food groups, *3*) the a priori diet-quality score, and *4*) meat and fruit-vegetable dietary patterns. All models included adjustment for age, center, education, smoking status, physical activity, BMI, and energy intake. Models that used the entire cohort were adjusted for race-sex subgroups, and all models were repeated stratified by race-sex subgroups. To guard against overfitting, we used stepwise backward-elimination to produce more parsimonious models. Patterns of significance and model coefficients were not substantially different, and thus, we present results of the full models in this article.

With recognition that physical activity, BMI, and energy intake all could be in the causal pathways between diet and CRF, we also fit models by using all covariates except these 3 covariates. We constructed additional models by considering each covariate independently and all 3 covariates simultaneously. Again, the model coefficients were not markedly different whether covariates were considered separately or together, and thus, only full models with all 3 covariates together are presented. We examined quantile-quantile plots and scatterplots of residuals for all final models to check for the normality and homoscedasticity of errors. For the a priori diet-quality score and meat and fruit-vegetable dietary patterns, we fit fully adjusted generalized additive models and allowed the dietary score and patterns to have nonlinear associations with fitness. Pronounced nonlinearity was observed only for the fruit-vegetable dietary pattern. For that pattern, the nonlinearity was seen only for observations near the extremes of the observed range, and model diagnostics suggested that the linear fit was adequate. Therefore, for simplicity, we present only the results of the linear models.

Because of the large number of models and food groups, adjustment for multiple comparisons may have been an issue. An observed $P < 0.0001$ was well below the adjusted threshold for significance that would have been derived by using the Bonferroni correction, which is known to be overly conservative.

In a sensitivity analysis, we repeated regression analyses for dietary patterns and treadmill duration overall and for race-sex subgroups by excluding 363 participants (13.8%) who did not attain 85% of the predicted maximum heart rate during the treadmill testing. We also examined the interrelations among diet, activity, and CRF by calculating adjusted means of the treadmill duration by quartiles of the a priori diet-quality score stratified by the physical activity score on the basis of self-report. In fully adjusted linear models, we tested interaction terms between quartiles of the a priori diet-quality score and dichotomized physical activity by considering quartiles both as factors and as an ordinal variable. Main analyses were performed with SAS statistical software (version 9.2); generalized additive models were fit by using R version 2.15.2 software (R Foundation for Statistical Computing).

RESULTS

The mean age of participants at the year 20 exam was ∼45 y, and black participants were slightly younger than their white counterparts (**Table 2**). The highest education achievement was, on average, 2 y less in blacks than whites, and blacks and men had a higher prevalence of current smoking than that of whites and women, respectively. Black men had the highest mean (±SD) physical activity score (442 ± 351), whereas black women had the lowest physical activity score (241 ± 228). Mean BMI for all participants was 29.1 ± 7.0, with the highest BMI in black women (32.1 ± 7.4) and the lowest BMI in white women (26.9 ± 6.5). The mean treadmill duration in white men (550 ± 137 s) was >2 min longer than the overall mean (427 ± 161 s), whereas the duration in black women (292 ± 110 s) was >2 min shorter. Black men and white women had intermediate values. The mean energy expended during the treadmill testing ranged from 16.1 ± 7.7 METs in black women to 37.8 ± 13.5 METs in white men. Although energy intake was nearly equal in

TABLE 2

Characteristics of study participants at year 20 overall and by race-sex subgroups[1]

	Total (*n* = 2632)	White men (*n* = 667)	Black men (*n* = 464)	White women (*n* = 775)	Black women (*n* = 726)	*P*[2]
Age (y)	45.2 ± 3.6[3]	45.7 ± 3.3	44.5 ± 3.5	45.8 ± 3.4	44.6 ± 3.9	<0.0001
Education (last grade completed)	15.1 ± 2.6	15.9 ± 2.8	13.9 ± 2.2	16.0 ± 2.4	14.2 ± 2.2	<0.0001
Current smoking (%)	17.4	13.3	27.2	12.1	20.5	<0.0001
Physical activity score	358 ± 279	423 ± 263	442 ± 351	351 ± 255	241 ± 228	<0.0001
BMI (kg/m^2)	29.1 ± 7.0	28.4 ± 6.3	29.3 ± 6.1	26.9 ± 6.5	32.1 ± 7.4	<0.0001
GXT duration (s)	427 ± 161	550 ± 137	455 ± 130	427 ± 143	292 ± 110	<0.0001
GXT energy expended (METs)	27.5 ± 13.9	37.8 ± 13.5	29.9 ± 10.9	26.6 ± 12.2	16.1 ± 7.7	<0.0001
Energy intake (kcal/d)	2331 ± 1038	2650 ± 990	2860 ± 1321	2033 ± 736	2016 ± 922	<0.0001
A priori diet-quality score[4]	62.6 ± 13.0	64.1 ± 11.9	55.0 ± 11.9	69.7 ± 11.9	58.6 ± 11.4	<0.0001
Food groups (servings/d)						
Fruit	2.65 ± 2.43	2.67 ± 2.56	3.00 ± 2.75	2.34 ± 1.89	2.72 ± 2.56	<0.0001
Vegetables, excluding potatoes	3.72 ± 2.82	3.89 ± 2.55	3.35 ± 3.33	4.35 ± 2.83	3.15 ± 2.52	<0.0001
Vegetables, potatoes	0.46 ± 0.57	0.53 ± 0.54	0.64 ± 0.90	0.35 ± 0.39	0.40 ± 0.42	<0.0001
Grains	6.59 ± 3.70	7.78 ± 3.74	8.22 ± 4.55	5.73 ± 2.79	5.36 ± 3.15	<0.0001
Meats and fish	5.31 ± 3.48	5.89 ± 3.46	7.24 ± 4.41	4.01 ± 2.42	4.94 ± 3.10	<0.0001
Dairy	2.44 ± 2.71	2.95 ± 2.83	2.14 ± 2.91	2.88 ± 3.06	1.68 ± 1.64	<0.0001
Fats	5.43 ± 5.96	6.18 ± 6.92	6.55 ± 6.42	4.83 ± 5.42	4.68 ± 4.99	<0.0001
Beans	0.25 ± 0.42	0.28 ± 0.50	0.30 ± 0.58	0.24 ± 0.33	0.20 ± 0.28	0.0001
Eggs/omelets	0.59 ± 0.76	0.58 ± 0.57	0.89 ± 1.01	0.49 ± 0.82	0.52 ± 0.60	<0.0001
Seeds, nuts, peanut butter	1.16 ± 2.01	1.31 ± 1.79	1.11 ± 2.31	1.23 ± 1.93	0.98 ± 2.06	0.0131
Salad dressings/sauces	2.33 ± 2.08	2.42 ± 1.85	2.94 ± 2.72	1.90 ± 1.75	2.31 ± 2.03	<0.0001
Soups	0.05 ± 0.09	0.07 ± 0.11	0.05 ± 0.09	0.06 ± 0.09	0.04 ± 0.06	<0.0001
Soy/nondairy products	0.79 ± 2.28	0.64 ± 1.66	0.66 ± 1.93	0.99 ± 2.41	0.81 ± 2.77	0.0148
Pickled foods	0.45 ± 1.17	0.49 ± 0.79	0.39 ± 0.69	0.50 ± 1.74	0.38 ± 0.92	0.1148
Chocolate	0.18 ± 0.39	0.23 ± 0.45	0.18 ± 0.40	0.19 ± 0.41	0.13 ± 0.29	<0.0001
Sweet extras	1.76 ± 3.60	1.66 ± 3.18	2.47 ± 5.39	1.25 ± 2.03	1.94 ± 3.74	<0.0001
Sugar substitutes	0.71 ± 3.06	0.68 ± 3.76	0.27 ± 1.65	1.10 ± 3.90	0.58 ± 1.66	<0.0001
Beverages	4.61 ± 3.58	6.00 ± 4.04	4.30 ± 3.73	4.98 ± 3.32	3.14 ± 2.58	<0.0001

[1] GXT, graded exercise treadmill; MET, metabolic equivalent task.

[2] Omnibus ANOVA *P* value for characteristic by race-sex subgroups.

[3] Mean ± SD (all such values).

[4] Created by classifying the 46 nuanced food groups as beneficial (20 groups), adverse (13 groups), or neutral (13 groups) in terms of their hypothesized disease relations. The score was the sum of category scores 0–4 for the beneficial food groups plus scores in reverse order (4–0) for the adverse food groups depending on the level of consumption of that group. Food groups rated as neutral were not included in the calculation of the score. The range of possible scores was 0 to 132.

white and black women, black men consumed an average of 210 kcal/d more than white men did ($P = 0.0004$). Consistent with an earlier report (20), white women had the highest mean a priori diet-quality score (69.7 ± 11.9), whereas black men had the lowest score (55.0 ± 11.9). *P* values for all differences in participant characteristics described were <0.0001, unless otherwise noted. Significant differences were noted in the mean daily intake of all major food groups (with the exception of pickled foods) in the 4 race-sex subgroups. *See* Supplemental Table 1 under "Supplemental data" in the online issue for mean daily intakes of major and nuanced food groups overall and in race-sex subgroups.

Results of linear regression modeling CRF (treadmill duration) as a function of intake of individual food groups in all participants (**Table 3**) showed that whole-grain foods, refined grains, grain desserts, processed meats, oil, coffee, meal-replacement drinks, beer, and wine were significantly and positively associated with the treadmill duration ($P < 0.05$ for each). Whole fruit (not juices), organ meats, fried meats and fish, and soy and nondairy products were significantly and negatively associated with the treadmill duration ($P < 0.05$ for each). There were no consistent associations of individual food groups with the treadmill duration by race-sex subgroups with the following exception: there was a strong positive association of wine intake in all subgroups, although this was not statistically significant in black men ($P < 0.05$ for other race-sex subgroups).

Results of the linear regression models for CRF as a function of the dietary quality score and patterns (**Table 4**) showed that the a priori diet-quality score was positively associated with the treadmill duration overall and in all subgroups, although this was not statistically significant in black men ($P < 0.001$ for other race-sex subgroups). The meat pattern was strongly negatively associated with the treadmill duration in whites only ($P < 0.0001$ in white men and $P < 0.05$ in white women). The fruit-vegetable pattern was positively associated with the treadmill duration only in white men ($P < 0.05$).

In regression analyses for the dietary score and patterns and the treadmill duration overall and for the race-sex subgroups with the exclusion of participants who did not attain 85% of the predicted maximum heart rate during treadmill testing, only 1 of 15 coefficients changed from significant to nonsignificant (fruit-vegetable dietary pattern in white men) and the direction of the association did not change (data not shown).

With recognition of the potential for interrelations in diet, physical activity, and CRF, we examined these variables jointly in additional detail. We calculated the mean treadmill duration by quartiles of the a priori diet-quality score stratified by high and low self-reported physical activity split at the median score of 294, with adjustments as shown in Table 4; thus, we depicted an interaction between physical activity and diet. The adjusted mean treadmill duration in subjects with low activity ranged from 403.4 s (95% CI: 393.5, 413.3 s) for subjects in the lowest quartile of the a priori diet-quality score to 429.5 s (95% CI: 415.6, 443.4 s) for subjects in the highest quartile of the a priori diet-quality score, with a difference of 26 s. In subjects with high activity, the adjusted mean duration was 442.3 s (95% CI: 429.6, 455.1 s) for subjects in the lowest quartile of the a priori diet-quality score and 517.0 s (95% CI: 506.7, 527.2 s) for subjects in the highest quartile of the a priori diet-quality score, with a difference of 75 s. The adjusted (least-squares means) graded relation between quartiles of the a priori score and treadmill duration across activity levels is shown in **Figure 1** and reveals that, although both diet and activity were associated with CRF, the relation differed between activity levels. The a priori diet-quality score was significantly associated with CRF within activity levels ($P < 0.001$ for both). In an adjusted linear model, there was a significant interaction between the a priori diet-quality score quartile treated as an ordinal variable and low compared with high activity ($P < 0.001$). When interaction terms were examined separately with each quartile treated as a factor, there was a significant interaction between high activity and the highest quartile of the a priori diet-quality score ($P < 0.001$); in subjects in the highest a priori diet-quality score quartile, the mean treadmill duration was 48.6 s longer in subjects with high than low physical activity as estimated by the adjusted model coefficient (data not shown).

DISCUSSION

In this cross-sectional analysis, we showed that the a priori diet-quality score was associated with a greater treadmill duration overall and in all race-sex subgroups except black men. The meat dietary pattern was negatively associated with CRF in white men and white women. In analyses of foods and food groups, we showed a greater consumption of grains (both whole and refined) was associated with longer treadmill duration overall. The consumption of certain beverages was positively associated with CRF overall, and wine consumption in particular was positively associated with treadmill duration in all race-sex subgroups except black men. Finally, we showed that blacks (especially black men) had less-healthy diets than those of whites as assessed by using the a priori diet-quality score.

Few previous studies have investigated associations in objectively measured CRF and various dietary constituents. Most previous studies have focused on macronutrients and micronutrients, and results have been inconsistent. Brodney et al (3) showed lower intakes of carbohydrate, fiber, calcium, folate, vitamin B-6, vitamin A, and vitamin C and higher intakes of total fat, saturated fat, monounsaturated fat, and cholesterol in men and women with low fitness than in subjects with high fitness assessed by a maximal exercise treadmill test. Dietary fiber intake was significantly lower in men and women in the lowest tertile of fitness than in subjects in the highest tertile of fitness as assessed by the $\dot{V}O_2$max at exhaustion in a cycle ergometer test (5). However, CRF assessed by $\dot{V}O_2$max on a bicycle ergometer was not associated with macronutrient intakes in a cross-sectional study of participants in the Penn State Young Women's Health Study (11). In a cross-sectional analysis in white and black men and women with above-optimal blood pressure in the PREMIER blood pressure control through lifestyle approaches clinical trial, dietary fat and fiber intakes were not associated with CRF (assessed by a submaximal treadmill exercise test) in any race-sex subgroup. Saturated fat intake was significantly higher in participants with poor or below-average CRF than in subjects with average or above-average CRF in nonblack men only (8). In a cross-sectional study of dietary intake and CRF (assessed by maximal GXT tests) in 34 young women, CRF was positively associated with intakes of protein, carbohydrate, fiber, niacin, vitamin B-6, pantothenic acid, potassium, magnesium, iron, zinc, calcium, and phosphorus (7).

TABLE 3
Linear regression coefficients modeling cardiorespiratory fitness (treadmill duration in seconds) at year 20 as a function of daily servings of food groups at year 20, overall and stratified by race-sex subgroups[1]

Food groups	Total (n = 2529)	White men (n = 649)	Black men (n = 444)	White women (n = 752)	Black women (n = 684)
Fruit (servings/d)					
Fruit	−3.34 ± 1.52*	1.97 ± 2.50	−6.78 ± 3.36*	−1.93 ± 2.67	0.17 ± 2.17
Fruit juices	2.36 ± 1.86	7.22 ± 3.34*	3.97 ± 3.06	−2.56 ± 4.48	−1.39 ± 2.56
Vegetables, excluding potatoes (servings/d)					
Green leafy	4.72 ± 2.89	10.05 ± 5.18	9.52 ± 7.80	7.78 ± 3.89*	1.39 ± 5.00
Dark yellow	−8.71 ± 6.17	29.34 ± 13.07*	−28.34 ± 15.03	−6.32 ± 7.63	10.83 ± 11.72
Tomatoes	2.05 ± 4.94	−10.48 ± 10.58	9.96 ± 10.56	4.75 ± 7.48	−0.63 ± 6.58
Avocados/guacamole	3.65 ± 5.30	−10.66 ± 10.97	13.82 ± 15.61	6.56 ± 5.84	13.87 ± 11.35
Other	−2.05 ± 2.03	2.04 ± 4.04	2.09 ± 3.90	−0.01 ± 3.13	−0.67 ± 3.34
Vegetables, potatoes (servings/d)					
Potatoes	−3.48 ± 5.69	−21.79 ± 10.70*	−11.21 ± 8.87	1.87 ± 10.85	0.21 ± 11.46
Fried potatoes	7.44 ± 9.25	−23.89 ± 18.79	12.37 ± 13.09	−27.59 ± 24.52	14.45 ± 13.86
Grains (servings/d)					
Whole-grain foods	12.50 ± 1.91§	4.88 ± 3.52	7.54 ± 3.55*	8.20 ± 3.17†	4.31 ± 3.17
Refined grains	5.51 ± 1.64‡	2.38 ± 2.89	1.13 ± 2.98	7.05 ± 2.99*	−1.47 ± 2.67
Sweet breads	0.47 ± 3.23	5.59 ± 6.31	2.16 ± 5.45	4.75 ± 4.97	−9.89 ± 6.13
Salty snacks	−1.62 ± 4.28	9.22 ± 9.48	−9.54 ± 12.85	−1.57 ± 4.95	6.45 ± 8.37
Grain desserts	8.34 ± 2.73†	4.02 ± 4.23	4.39 ± 4.69	23.94 ± 7.27†	7.65 ± 5.53
Meats and fish (servings/d)					
Red meat regular	2.24 ± 2.30	−11.84 ± 4.04†	2.65 ± 4.24	−2.09 ± 4.66	5.92 ± 3.45
Red meat lean	7.07 ± 3.78	0.33 ± 6.16	2.49 ± 6.36	−6.94 ± 7.11	−12.96 ± 8.58
Processed meats	5.76 ± 2.76*	−0.34 ± 4.68	10.09 ± 4.60*	−4.27 ± 5.83	0.09 ± 4.53
Organ meats	−54.14 ± 22.37*	−51.27 ± 54.87	17.76 ± 29.89	−65.63 ± 67.72	−109.33 ± 29.32‡
Poultry	0.85 ± 1.73	2.62 ± 3.26	−1.18 ± 3.10	8.04 ± 3.43*	0.78 ± 2.54
Fish	31.02 ± 17.76	19.14 ± 21.55	33.09 ± 44.93	28.93 ± 45.00	−9.72 ± 36.61
Fried (fish, chicken, shellfish)	−9.78 ± 4.63*	14.26 ± 10.38	−9.50 ± 7.09	−46.31 ± 18.51*	−2.22 ± 5.49
Lean fish	−0.03 ± 2.52	0.60 ± 4.97	7.55 ± 5.12	−3.92 ± 4.42	0.47 ± 3.37
Shellfish	−5.76 ± 4.95	−2.74 ± 9.63	3.56 ± 7.31	−7.35 ± 12.33	3.90 ± 7.23
Dairy (servings/d)					
Low fat	−1.05 ± 1.63	−3.58 ± 2.48	0.11 ± 4.20	−1.72 ± 2.60	4.93 ± 3.64
Whole fat	2.07 ± 1.37	3.32 ± 3.35	8.22 ± 4.24	3.01 ± 1.46*	3.14 ± 2.95
Fats (servings/d)					
Margarine	−1.96 ± 1.72	0.95 ± 3.70	4.17 ± 3.12	−0.50 ± 2.90	−1.48 ± 2.22
Oil	1.22 ± 0.60*	0.96 ± 1.00	1.14 ± 1.32	2.64 ± 1.00†	−0.30 ± 0.95
Butter	−1.03 ± 1.04	0.78 ± 1.44	−1.26 ± 2.25	−1.92 ± 2.02	0.41 ± 1.85
Beans	10.49 ± 5.96	7.57 ± 9.49	1.13 ± 9.65	10.49 ± 11.91	12.34 ± 12.12
Eggs/omelets	−0.02 ± 3.32	−26.15 ± 8.57†	5.80 ± 5.19	−8.24 ± 5.54	5.24 ± 5.81
Seeds, nuts, peanut butter	1.98 ± 1.49	1.63 ± 2.98	7.19 ± 2.87*	3.24 ± 2.61	−3.26 ± 2.06
Salad dressings/sauces	−1.33 ± 1.48	−1.47 ± 3.15	2.37 ± 2.72	1.50 ± 3.04	1.93 ± 2.09
Soups	31.17 ± 26.27	−38.26 ± 41.52	8.28 ± 58.28	26.81 ± 38.70	44.25 ± 50.91
Soy/nondairy products	−2.51 ± 1.11*	2.30 ± 2.63	3.47 ± 3.44	−0.36 ± 1.79	0.36 ± 1.28
Pickled foods	−3.00 ± 2.00	−0.02 ± 6.24	−21.75 ± 7.90†	−1.64 ± 1.95	−2.51 ± 3.71
Chocolate	4.01 ± 6.50	−5.68 ± 10.29	14.33 ± 15.00	18.90 ± 9.22*	−19.69 ± 13.70
Sweet extras	0.46 ± 0.66	0.44 ± 1.37	1.91 ± 0.99	0.41 ± 1.73	0.07 ± 0.92
Sugar substitutes	0.89 ± 0.77	2.31 ± 1.13*	2.43 ± 2.96	0.43 ± 1.00	−0.21 ± 2.07
Beverages (servings/d)					
Sugar-sweetened soft drinks	−1.26 ± 2.09	−6.48 ± 4.13	−0.96 ± 3.68	1.14 ± 4.46	0.19 ± 2.70
Diet soft drinks	0.26 ± 1.45	−1.56 ± 2.15	5.66 ± 3.31	−3.88 ± 2.14	−1.87 ± 3.58
Coffee	5.40 ± 1.28§	1.46 ± 1.88	−7.36 ± 4.04	−0.24 ± 2.01	3.13 ± 2.86
Tea	0.10 ± 1.59	−1.55 ± 2.38	−10.75 ± 6.73	2.99 ± 2.22	0.56 ± 3.19
Meal replacement drinks	12.81 ± 4.59†	9.84 ± 8.35	7.80 ± 6.20	−4.71 ± 12.77	−1.92 ± 8.55
Beer	15.18 ± 3.25§	4.88 ± 4.91	−2.80 ± 5.66	11.00 ± 9.10	2.77 ± 5.67
Liquor	1.83 ± 2.89	−5.11 ± 8.10	0.44 ± 4.10	6.36 ± 4.92	6.03 ± 4.67
Wine	13.28 ± 3.50§	16.92 ± 5.67†	17.33 ± 13.64	13.44 ± 4.58†	17.51 ± 7.15*

[1] All values are variable estimates ± SEs. All models were adjusted for age, center, education, smoking status, physical activity, BMI, and energy intake. Coefficients represent the predicted change in treadmill duration in seconds per daily serving of each food group. *,§,†,‡ P values were derived from t statistics of model coefficients in fully adjusted models: *$P < 0.05$, §$P < 0.0001$, †$P < 0.01$, ‡$P < 0.001$.

TABLE 4

Linear regression coefficients modeling separately cardiorespiratory fitness (treadmill duration in seconds) at year 20 as a function of a priori diet-quality score and meat and fruit-vegetable dietary patterns (derived by principal components analysis) at year 20, overall and stratified by race-sex subgroups[1]

Dietary score/pattern	Total (n = 2529)	White men (n = 649)	Black men (n = 444)	White women (n = 752)	Black women (n = 684)
A priori diet-quality score	0.76 ± 0.20‡	2.23 ± 0.39§	0.45 ± 0.42	1.47 ± 0.32§	0.97 ± 0.29‡
Meat dietary pattern	−5.76 ± 4.83	−36.71 ± 8.24§	2.82 ± 7.58	−18.82 ± 9.04*	−5.97 ± 7.56
Fruit-vegetable dietary pattern	−3.19 ± 3.14	11.65 ± 5.45*	4.72 ± 5.59	5.21 ± 5.23	0.93 ± 4.55

[1] All values are variable estimates ± SEs. All models were adjusted for age, center, education, smoking status, physical activity, BMI, and energy intake. Coefficients represent the predicted change in treadmill duration in seconds per point of the score or patterns. ‡,§,*P values were derived from t statistics of model coefficients in fully adjusted models: ‡$P < 0.001$, §$P < 0.0001$, *$P < 0.05$.

A focus on food groups and dietary scores and patterns may be more relevant to actual dietary intake in humans than the investigation of individual nutrient associations with CRF. However, few studies have examined associations of CRF with food groups and overall dietary patterns. In the Penn State Young Women's Health Study, daily servings of milk, bread, fruit, vegetables, and meat were not associated with CRF (11). Daily servings of fruit and vegetables did not differ significantly in white and black men and women with poor or below-average CRF compared with subjects with average or above-average CRF in the PREMIER trial (8).

We noted a strong positive association between wine consumption and CRF (although this was not statistically significant in black men). There are few reports in the literature on the association between alcohol intake and CRF. In one report of a study of the determinants of CRF in men aged 42–60 y enrolled in the Kuopio Ischaemic Heart Disease Risk Factor Study, alcohol was not associated with CRF as assessed by $\dot{V}O_2$max (25). However, only the association with total alcohol intake was reported in the study; associations by the type of alcohol (ie, wine, beer, and liquor) were not reported. It is possible that the association between wine consumption and CRF resulted from residual confounding.

Other findings from this study were noteworthy. Some food groups (eg, wine), the a priori diet-quality score, and the meat dietary pattern were associated with the treadmill duration in all race-sex subgroups except for black men in some cases and black men and women in others. Reasons for these differences in diet and CRF associations by race are not clear but warrant additional study. Note that a baseline reliability study of nutrient consumption from the diet history showed that sex- and energy-adjusted 1-mo test-retest correlations were lower for blacks (0.27–0.58) than whites (0.54–0.82). We also noted that the association between diet and CRF differed by activity level and was somewhat stronger in subjects who were more physically active than in subjects who were less active.

This study had several strengths, including the large sample size and nearly equal representation of men and women and blacks and whites, the use of an objective measure of CRF, and the comprehensive assessment of diet, including the assessment of the overall diet through food groups and dietary patterns. The results of this study may not be generalizable beyond black and white middle-aged adults. When results of this study are interpreted, it is important to note that, although CRF is often considered an objective measure of habitual physical activity (3), CRF may be influenced by a multitude of other factors. For example, ≤50% of CRF may be genetically determined (4), potentially limiting the ability to change CRF. Finally, because of the cross-sectional nature of the study, results should be interpreted as describing observed associations and not causal relations.

In conclusion, the a priori diet-quality score was positively associated with CRF in this group of black and white adults, whereas the meat dietary pattern was negatively associated only in whites, and the fruit-vegetable pattern showed little association. The lack of associations of the diet-quality score or dietary patterns with CRF in black men requires additional study.

The authors' responsibilities were as follows—JMS, DRJ, and JSR: designed the research and analyzed data; JMS, DRJ, CEL, LMS, and BS: conducted the research; JMS: had primary responsibility for final content of the manuscript; and all authors: wrote the manuscript and read and approved the final manuscript. None of the authors had a conflict of interest.

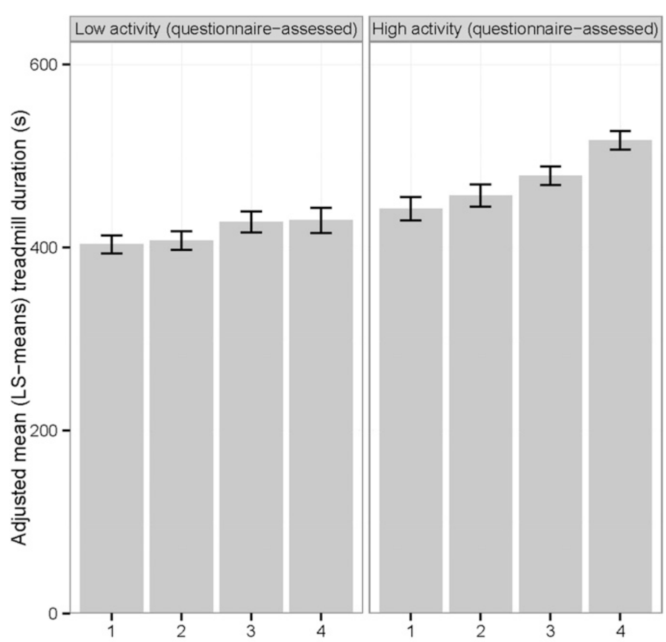

FIGURE 1. Adjusted (LS means) mean (95% CI) treadmill duration in seconds by quartiles of the a priori diet-quality score stratified by high and low self-reported physical activity (above compared with below the median score of 294). A priori diet-quality score categories were ≤54, >54 to ≤63, >63 to ≤73, and >73. Smallest groups were the off diagonal: lowest quartile a priori diet-quality score with high activity (n = 216) and highest quartile a priori score with low activity (n = 176), whereas largest groups were subjects with the lowest quartile a priori score and low activity (n = 372) and subjects with the highest quartile a priori score and high activity (n = 350). LS, least-squares.

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