Original Article

Relationship between diet quality and carotid intima-media thickness in people with and without carotid atherosclerosis

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Abstract

Background: Dietary assessment and management appear to be essential to limit the impact of cardiovascular risk. **Aim:** This study aims to assess the association between diet quality as measured by Alternate Healthy Eating Index (AHEI) and coronary risk as determined by carotid artery intima-media thickness (CIMT) among Saudi adults. **Methods:** A case–control study was conducted in 210 participants who were matched for age and sex and recruited sequentially from King Abdulaziz University Hospital, Jeddah, Saudi Arabia. Demographic and anthropometric variables were measured in all study participants. Dietary intake was measured by food frequency questionnaire. **Results:** Obesity was highly prevalent among the study population. The mean AHEI score for the total sample was found to be 58.3 ± 1.67. There were no differences according to the presence and absence of atherosclerotic disease; 45% had a poor diet, and 39% had a diet that needs improvement. Participants with higher CIMT values tended to be of lower AHEI category. Negative correlations were observed between CIMT and AHEI scores and components after adjustment for age and energy intake. **Conclusions:** Adherence to a healthier diet, as reflected by a higher AHEI score, is associated with lower coronary risk, as estimated by CIMT value, independently from obesity and personal behavior factors.

Keywords: Alternate Healthy Eating Index, atherosclerosis, carotid artery intima-media thickness, food frequency questionnaire, obesity

Introduction

Diet is an important modifiable cardiovascular risk factor.[1] It is widely recognized, that combination of foods consumed, expressed as dietary patterns, and their potential synergistic effects are important in the prevention of chronic diseases rather than the impact of individual nutrients..[2,3] This has led to the development of methods that can be used for the characterization of these dietary patterns.

Several diet quality indices, based on established nutrient requirements and dietary guidelines, have been developed to evaluate the health benefits of individual diets. These scores, reflecting overall diet quality, can help researchers to sort through the nutrient and food-specific findings and provide a measure of diet that incorporates nutrient and food interactions of likely biological importance.[4,5]

Dietary indices represent a measure of "healthy" eating patterns and are known by various names including diet quality indices or healthy eating indices.[6] Dietary Guidelines aim to provide science-based dietary advice that promotes good health and reduces major chronic diseases.[4]

The Healthy Eating Index (HEI), which quantifies the adherence to dietary guidelines, was associated with only a modest reduction in risk of major chronic disease.[7] Although such indices are based on the U.S. dietary guidelines, they

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have been adapted for use in other countries by altering the threshold values.[8] Recently, the Alternate HEI (AHEI) was created that was based on foods and nutrients predictive of chronic disease risk.[9] This diet score, including 11 components, was associated with a 16% lower risk of major chronic diseases (cardiovascular disease, diabetes, and cancer). Several studies have confirmed the relevance of the AHEI-2010 diet score as being associated with lower incidence of obesity,[10] healthy aging and well-being[11] and a reduced risk of all cause, cardiovascular, and cancer mortality.[12]

The dietary guidelines and recommendations for the Kingdom of Saudi Arabia were recently issued by the Saudi Ministry of Health and were developed to maintain the health and reduce the risk of chronic diseases in the Saudi population. The food guide, palm, was created to provide more specific guidance in the selection and quantity of daily food choices.[13] Therefore, it seemed important to assess and to monitor adherence to these guidelines through a dietary scoring system to rate the quality of diet among Saudi people.

Dietary assessment and management appear to be essential to limit the impact of cardiovascular risk.[14] Plaque instability and thrombosis are also important determinants of cardiovascular end-points such as acute coronary syndromes and stroke, in the presence of significant atherosclerosis. Carotid artery intima-media thickness (CIMT) is a validated surrogate marker of preclinical atherosclerosis that has been shown to predict cardiovascular morbidity and mortality.[15]

However, data are scarce with respect to whole dietary patterns and their relationship to disease within populations. Furthermore, the vast majority of these studies have been conducted in Western populations. Since the development of the AHEI, substantial evidence has emerged to support a role of additional dietary factors in the development of chronic diseases. Given the lack of national dietary studies, we aimed to assess the association between diet quality, as measured by AHEI and coronary risk as determined by CIMT among Saudi adults.

Methods

A total of 210 participants were recruited sequentially from the outpatient clinics of the internal medicine department at King Abdulaziz University Hospital (KAUH) in Jeddah, Saudi Arabia. Participants were originally referred to this service by their general practitioner, and the cohort consisted of a mixture of both new and returning patients. A control Group of similar age and sex was recruited from the same catchment area as the case participants in a case–control study design. The study was approved by the Ethical Committee of KAUH. Exclusion criteria included a documented history of cardiovascular disease, renal disease, hepatic disease, or chronic inflammatory disease. A total of 105 age- and sex-matched individuals without diabetes were recruited from the same catchment site. None of the patients were receiving any medication that could interfere with our assessment (e.g., antioxidants supplements, anti-inflammatory drugs, and antiobesity therapies).

Data were collected using a structured questionnaire, which included questions on demographic factors, such as gender, age, marital status, education attainment, employment status, and use of medication(s). A family history of coronary heart disease (CHD) was defined as a history of sudden death, myocardial infarction, or coronary revascularization in a relative before the age of 55 (males) or 65 (females). Smoking status was categorized as never smoker, exsmoker, or current smoker. To assess the physical activity, participants were asked to report the frequency of spending at least 20 min of continuous physical activity that was performed <1 time, 1–2 times, or at least 3 times/week.[16]

Dietary intake was determined using a previously validated semiquantitative food frequency questionnaire (FFQ).[17] For each food item, a commonly used portion size was specified, and the participants were asked how often, on average, he or she had consumed that quantity over the past year. Frequencies ranged from "never" to "two or more servings per day." Nutrients intakes were calculated by multiplying the frequency of intake for each food by its nutrient content and summing nutrient contributions across all food items.[18] Nutrient analysis was conducted using a software program incorporating the use of McCance and Widdowson's Food composition tables[19] editions with supplements.[20]

To assess overall diet quality, the AHEI-2010 was used and scored as described in detail elsewhere.[9] The criteria for scoring each component are listed in Table 1. The AHEI-2010 is based on 11 components: the ideal intake for six of these was set at the highest intake (Vegetables, fruit, whole grains, nuts and legumes, long-chain omega-3 fats [Docosahexaenoic acid and eicosapentaenoic acid], and polyunsaturated fatty acids), one component for which moderate intake was considered to be ideal (alcohol), and four components for which avoidance or lowest intake was considered to be ideal (sugar-sweetened drinks and fruit juice, red and processed meat, trans fat, and sodium). Each component is given a minimal score of 0 and a maximal score of 10, with intermediate values scored proportionally, and has the potential to contribute 0–10 points to the total score. All the component scores are summed to obtain a total AHEI-2010 score, which ranges from 0 to 100, with a higher score representing a healthier diet. Recommended HEI criteria classifies the diet quality with scores of 81 or higher as "good" scores, between 51 and 80 as "needs improvement," and scores under 50 as "poor."[21]

Resting blood pressure was measured using an automated sphygmomanometer and was recorded as the average of three measurements taken 5 min apart with the participant sitting.

All anthropometric measures were carried out with participants wearing light clothing and with shoes removed. Height and

Table 1: Healthy Eating Index-2010 components and standards for scoring (Chiuve *et al.*,2012)

Component	Optimum score	Standard for maximum score	Standard for minimum score of zero
Adequacy			
Total fruit[a]	5	≥0.8 cup eq/1000 kcal	No fruit
Whole fruit[b]	5	≥0.4 cup eq/1000 kcal	No whole fruit
Total vegetables[c]	5	≥1.1 cup eq/1000 kcal	No vegetables
Greens and beans[c]	5	≥0.2 cup eq/1000 kcal	No dark-green
Whole grains	10	≥1.5 oz eq/1000 kcal	No whole grains
Dairy[d]	10	≥1.3 cup eq/1000 kcal	No dairy
Total protein foods[e]	5	≥2.5 oz eq/1000 kcal	No protein foods
Seafood and plant proteins[e,f]	5	≥0.8 oz eq/1000 kcal	No seafood or plant proteins
Fatty acids[g]	10	PUFAs + MUFAs/SFAs >2.5	PUFAs + MUFAs/SFAs ≤1.2
Moderation			
Refined grains	10	≤1.8 oz eq/1000 kcal	≥4.3 oz eq/1000 kcal
Sodium	10	≤1.1 g/1000 kcal	≥2.0 g/1000 kcal
Empty calories[h]	20	≤19% of energy	≥50% of energy

[a]Includes 100% fruit juice, [b]Includes all forms except fruit juice, [c]Includes any beans and peas not counted as total protein foods, [d]Includes all milk products, such as fluid milk, yogurt, cheese, and fortified soy beverages, [e]Beans and peas are included here (and not with vegetables) when the total protein foods standard is otherwise not met, [f]Includes seafood, nuts, seeds, soy products (other than beverages) as well as beans and peas counted as total protein foods, [g]Includes seafood, nuts, seeds, soy products (other than beverages) as well as beans and peas counted as total protein foods, [h]Calories from solid fats, alcohol, and added sugars; threshold for counting alcohol is >13 g/1000 kcal. PUFA: Polyunsaturated fatty acids; MUFA: Monounsaturated fatty acids; SFA: Saturated fatty acid

weight were measured using a SECA balance scale (Seca Corp, Columbia, MD). Body mass index (BMI) was calculated as weight/height^2 (kg/m^2). Waist girth was measured as the maximum abdominal circumference between the iliac crest and umbilicus.

Intima-media thickness was determined using a carotid ultrasound machine (IU22xmatrix ultrasound, Philips Health Care, USA) equipped with a 9-3 MHz linear transducer. The carotid arteries were scanned longitudinally over three carotid segments, using the optimal angle and the lateral extent of each carotid segment as defined relative to the tip of the flow divider, which is normally the most clearly defined anatomic reference in the proximity of the carotid bifurcation. The mean of the near and far walls of the maximum common CIMT from both sides of the neck (mean of four measurements) was used as the main outcome variable. The presence of carotid stenosis was assessed using echo-Doppler accepted criteria.[22] A plaque was defined as a focal wall region with CIMT ≥0.9 mm, protruding into the lumen.[23] This was used to define patients with subclinical carotid atherosclerosis.

Values are expressed as means and standard deviation. Continuous variables were assessed for normality of distribution by Kolmogorov–Smirnov test. Continuous variables that were skewed were log, square root, and inverse transformed as appropriate before statistical analyses were performed. Independent sample *t*-tests were used to test for differences between group means of normally distributed variables. Mann–Whitney U-tests were used to test for differences between group means of nonnormally distributed variables. The Chi-square test was used for determining the differences between categoric variables. All correlation analyses were controlled for potential confounding variables, for example, BMI. All P values were two-sided, with $P < 0.05$ indicating statistical significance.

Results

Personal behavior and medical history characteristics of the study population are presented in Table 2. The mean ± standard deviation age of the cohort was 57.8 ± 0.5 years. About one-third of the cohort was overweight as categorized by BMI value between 25 and 29.9 kg/m^2. Obesity, both overall (59%), and central (97%), were highly prevalent among the 210 study participants included in this analysis. The case group and the age- and sex-matched controls were comparable with regard to anthropometric measures, socioeconomic status, and smoking habits except for their physical activity level. Nearly 73% of the controls were physically inactive compared to 70% of the cases who reported performing physical activity 1–2 times/week ($P < 0.0001$). Approximately, one-third of the participants had a family history of heart diseases, one-third of the participants had a family history of peripheral vascular disease, and two-thirds had a family history of diabetes mellitus.

The mean AHEI score and the proportion of patients in each group are shown in Table 3. Of all AHEI components, the highest mean subscore was obtained for fatty acids (9.2 ± 0.2) and sodium (9.5 ± 0.5). The lowest subscores were attributed to the refined grains (4.1 ± 0.2) and "empty calories" (5.6 ± 0.8). The mean AHEI score for the total sample was 58.3 ± 1.67. About half of the total sample was classified as having a poor diet (i.e., ≤50), with higher scores representing a healthier diet.

There were no significant differences across categories of AHEI score with respect to their CIMT values ($P > 0.05$). However, patients with higher CIMT values tended to be of lower AHEI category [Figure 1].

An inverse relationship between CIMT values and the mean scores of AHEI (r=-0.197, $P < 0.01$) and its components, namely adequacy ($r = -0.143$, $P < 0.05$) and moderation ($r = -0.177$,

Table 2: Clinical characteristics of the study population (n=210)

	Controls without subclinical atherosclerosis (n=105)	Cases with subclinical atherosclerosis (n=105)	*P*
Age (years)	56.6±0.8	58.8±0.7	NS
Gender (female:male)	77:28	77:28	NS
Weight (kg)	83.9±1.8	79.9±1.6	NS
Height (cm)	159.9±0.8	159.1±0.9	NS
BMI (kg/m^2)	32.8±0.6	31.5±0.6	NS
WC (cm)	107.2±1.3	107.2±1.1	NS
Hip circumference (cm)	115.7±1.5	113.0±1.2	NS
WHR	0.93±0.0	0.95±0.0	NS
Presence of obesity			
Overall obesity (BMI ≥30 kg/m^2)	65 (62)	62 (56)	NS
Central obesity (WC ≥94 cm in men and ≥80 cm in women)	102 (97)	107 (96)	NS
WHR >0.90 in men and>0.85 in women	87 (83)	97 (87)	NS
SBP (mmHg)	135.7±2.0	141.1±2.1	NS
DBP (mmHg)	80.1±1.3	78.3±1.2	NS
Family history			
Heart diseases	32 (31)	35 (32)	NS
Diabetes mellitus	69 (66)	73 (66)	
Peripheral vascular diseases	28 (27)	24 (22)	
Marital status			
Married	88 (84)	99 (89)	NS
Divorced	4 (4)	1 (1)	
Widowed	13 (12)	11 (10)	
Educational level			
Primary school or less	54 (51)	65 (59)	NS
Intermediate school	7 (7)	10 (9)	
High school	23 (22)	16 (15)	
University and above	21 (20)	20 (18)	
Occupation			
Retired, unemployed	78 (74)	89 (80)	NS
Office worker	22 (21)	18 (17)	
Skilled professional	5 (5)	4 (4)	
Annual income (SR)			
<50,000	78 (74)	90 (81)	NS
50,000-100,000	21 (20)	16 (14)	
>100,000	6 (6)	5 (5)	
Physical activity level			
<1 time	77 (73)	32 (29)	<0.0001
1-2 times	28 (27)	78 (70)	
≥3 times	0 (0)	1 (1)	
Smoking habits			
Nonsmoker	88 (84)	89 (80)	NS
Ex-smoker	8 (8)	14 (13)	
Current smoker	9 (9)	8 (7)	

Numeric data are presented as mean±SD and categoric data as n (%). Continuous variables are compared by Mann–Whitney U-test and categorical data are compared by χ^2 test. BMI: Body mass index; DBP: Diastolic blood pressure; NS: Nonsignificant; SBP: Systolic blood pressure; WC: Waist circumference; WHR: Waist-hip ratio; SD: Standard deviation

P < 0.01), were demonstrated after adjustment for age and energy intake.

Discussion

The assessment of diet patterns may have a number of potential applications.[6] For example, they may be used to assess how well people comply with dietary guidelines and to monitor trends in the population over time. They may also be used as predictors of disease or as a summary of dietary behaviors to investigate interactions with other health behaviors or confounding of other exposure-disease relationships.[5]

Most previously published papers were conducted on apparently healthy young adults.[10] Although there are some reports about dietary intakes of patients with CHD, there are few studies on the quality of diet and whole diet indices among these patients.[24]

A lack of understanding of dietary guidelines and the misconceptions about healthy versus unhealthy food choices are

Table 3: Scores of Alternate Healthy Eating Index-2010 and its components among the study population (*n*=210)

AHEI component	Score range	Controls without subclinical atherosclerosis (*n*=105)	Cases with subclinical atherosclerosis (*n*=105)	*P*
Total fruit	0-5	3.24±0.1	3.43±0.1	NS
Whole fruit	0-5	3.05±0.1	3.11±0.1	NS
Total vegetables	0-5	3.5±0.27	3.3±0.24	NS
Greens and beans	0-5	3.52±0.3	3.32±0.2	NS
Whole grains	0-10	4.86±0.1	4.91±0.1	NS
Dairy	0-10	6.86±0.3	6.79±0.3	NS
Total protein foods	0-5	3.45±0.03	3.42±0.04	NS
Seafood and plant proteins	0-5	2.04±0.1	1.31±0.1	NS
Fatty acids	0-10	9.39±0.3	9.05±0.2	NS
Adequacy score	0-60	39.8±1.9	38.5±1.8	NS
Refined grains	0-10	4.71±0.2	3.56±0.2	NS
Sodium	0-10	9.69±0.5	9.32±0.4	NS
Empty calories	0-20	5.57±0.7	5.60±0.8	NS
Moderation score	0-40	19.9±1.1	18.4±1.1	NS
AHEI total score	0-100	59.7±2.4	56.9±2.3	NS
AHEI category	Good (scores≥81)	19 (18)	17 (15)	NS
	Needs improvement (scores: 51-80)	41 (39)	42 (38)	
	Poor (scores ≤50)	45 (43)	52 (47)	

Numeric data are presented as mean±SD and categoric data as *n* (%). Continuous variables are compared by Mann–Whitney U-test and categorical data are compared by χ^2 test. NS: Nonsignificant; AHEI: Alternate Healthy Eating Index; SD: Standard deviation

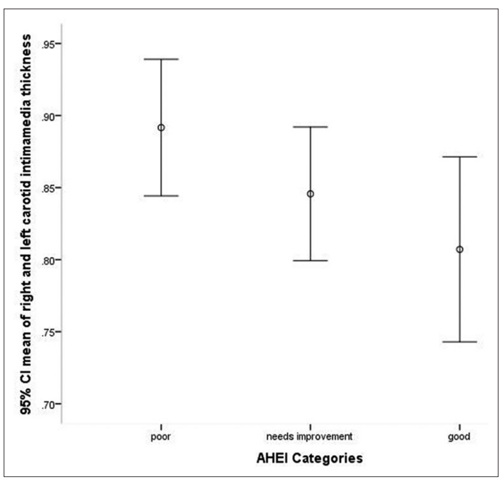

Figure 1: Error bars of 95% confidence intervals of mean values of carotid artery intima-media thickness among the study population (*n* = 210) as classified according to their Alternate Healthy Eating Index category. Participants' diets are categorized as "poor" (score ≤50), "needs improvement" (score from 51 to 80), and "good" (score ≥81)

a major obstacle to implementing a healthy diet policy.[25] In our study population, a lower AHEI score, which reflects an unhealthy dietary pattern, was associated with the presence of subclinical atherosclerotic disease, as estimated by CIMT ≥0.9 mm [Figure 1]. Consistent with previous large prospective follow-up studies that showed that there was a negative association between AHEI-2010 scores and cardiovascular diseases mortality was independent of BMI.[9] The majority of our study population were considered to have a poor dietary pattern irrespective of whether they were obese, as assessed by overall and central obesity anthropometric measures [Table 2]. A negative smoking history was reported by over 90% of the study cohort; however, this might be subjective to reporting or recall bias.

No significant difference was found in dietary patterns of individuals with and without subclinical atherosclerotic disease (P > 0.05). Given that the majority of our study participants were of poor socioeconomic status, they are likely to be less aware of a healthy dietary pattern, and this may partly explain their low AHEI scores. The unhealthy dietary pattern being followed by the majority of our study group indicates that the future dietary guidelines should be developed and promoted to address such patients with chronic diseases with special dietary needs. The previous studies have reported little or no association between HEI and the risk of major chronic diseases in large cohorts of health professional men and women.[26,27]

However, it is strongly believed that diet may contribute to the correlation between AHEI-2010 scores and the prevalence of cardiovascular risk factors.[28] Calorie intake differences by CIMT value may be a confounder in comparing AHEI index and its components.[29] In the present study, after the adjustments were made for age and energy intake, CIMT remained significantly inversely associated with AHEI and its components: adequacy and moderation. Moreover, there was no evidence supporting an association between CIMT and the individual components of the AHEI.

The AHEI-2010 supports a diet high in vegetables, fruit, whole grains, seafood, and legumes. This dietary pattern would contain carotenoids, ascorbic acids, phytochemicals, dietary fibers, omega-3 fatty acids, and other nutrients that are well-known to have cardioprotective effects.[30,31] Thus, more effective policy interventions for combatting cardiovascular risk factors are required. It has long been proposed that "Western" dietary patterns, that are high in red meat, processed meat, refined grains, and high-fat dairy products, are associated with higher coronary risk compared to the "healthy" dietary pattern rich in fruits, vegetables, fish, poultry, and whole grains.[32,33]

Additional quantitative quality indices have been developed for therapeutic diets such as the Mediterranean diet.[34] The current study provides important information that advances our understanding of dietary components impact over the prevention of clinical atherosclerotic disease. AHEI scores were evident of lower whole grains, seafood, and plant proteins consumption as well as higher fatty acids and sodium consumption in both study groups. AHEI components track the consumption of key nutrients that are associated with improved diet quality.[35]

Limitations of our study included the retrospective design, which cannot establish causality. The sample size was relatively small (n = 260). Our results cannot be generalized to the wider Saudi population since the study sample was not representative of the population at large. While FFQs are prone to greater measurement errors, their use allows a reasonable assessment of long-term diet.[36] Furthermore, the underreporting of calorie intake by overweight and obese individuals are likely to make our estimates of the association between HEI and CIMT more significant.

Conclusions

Adherence to a healthier diet, as reflected by a higher AHEI score, is associated with lower coronary risk, as estimated by CIMT value, independently from obesity and lifestyle factors. Future studies are warranted to determine the ability of the dietary score to predict the incidence of CVD end-points in longer-term follow-up.

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Conflicts of interest

There are no conflicts of interest.

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