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Healthy Eating Index and abdominal obesity

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Abstract

Objective: Although diet is a modifiable lifestyle factor to reduce abdominal obesity risk, the relationship between the Health Eating Index (HEI) and waist circumference (WC) has not been studied. The present study aimed to describe relationships between the HEI and abdominal obesity among adults.
Design: Secondary data analysis of a cross-sectional national survey, the Third National Health and Nutrition Examination Survey (NHANES III). The HEI data, including the total HEI score and HEI component scores, were collected with a 24 h recall. WC measures were taken during a physical examination. Abdominal obesity was defined as WC ≥ 102 cm for men and WC ≥ 88 cm for women. Other covariates were collected during an interview.
Subjects: In total 15 658 US adults, men (*n* 7470) and non-pregnant women (*n* 8188).
Results: The odds of abdominal obesity was 8·3 % (95 % CI 1·8, 14·9 %, $P = 0{\cdot}014$) lower for women and 14·5 % (95 % CI 6·8, 21·9 %, $P \leq 0{\cdot}001$) lower for men with each 10-unit increase in total HEI score (HEI scale, 0–100). For each point increase for the fruit score, abdominal obesity risk decreased by 2·6 % (95 % CI 0·8, 4·4 %, $P = 0{\cdot}007$) for women. Abdominal obesity risk decreased for men with each point increase in saturated fat and variety scores, by 3·1 % (95 % CI 0·1, 6·0 %, $P = 0{\cdot}042$) and 4·0 % (95 % CI 0·1, 7·7 %, $P = 0{\cdot}043$) respectively.
Conclusions: Dietary consumption that follows the HEI is associated with a lower risk for abdominal obesity.

Keywords
Healthy eating
Obesity
Diet
Nutrition

The rates of overweight and obesity have risen dramatically over the past 30 years in the USA[1]. Further, the WHO estimates that 1·6 billion adults worldwide are overweight, with 400 million of these adults obese[2]. Numerous health conditions and health complaints have been associated with obesity, and higher mortality has been observed among obese adults[3,4]. Moreover, self-reported health status of good or excellent drops dramatically for obese compared with normal-weight and overweight groups[5].

Obesity is a progressive condition, with many contributing factors such as behaviour, environment, heredity, socio-economic status and cultural influences[6]. Diet is an important lifestyle factor that has been related to body composition and may play a critical role in the prevention of obesity[7–9]. In addition to BMI, waist circumference (WC) is used to evaluate health risk. A WC measurement of ≥88 cm for women or ≥102 cm for men is defined as abdominal obesity[1,9]. Abdominal obesity has been associated with an increased risk of multiple diseases such as heart disease, diabetes, metabolic syndrome and some types of cancer[10,11].

Researchers are increasingly studying disease risk in relation to overall dietary patterns in addition to specific foods, nutrients or food components[12–16]. Multiple methods can be utilized to study dietary quality, including factor and cluster analysis or by using indices such as the Recommended Foods Score or the Healthy Eating Index (HEI). Previous research has reported relationships between the HEI and biomarkers for disease risk, with inverse relationships between HEI and BMI and serum levels of cholesterol, C-reactive protein, homocysteine, glucose and HbA_{1c}[14,17,18].

The total HEI score provides a picture of overall dietary quality, while the component scores used to calculate the total HEI score offer an opportunity to study important components of dietary intake and their relationship to abdominal obesity. The purpose of the present research was to study the associations between HEI, HEI component scores and abdominal obesity. Identifying relationships between abdominal obesity and the HEI is helpful for public health education regarding weight management. For the purposes of the study, abdominal adiposity was employed to define 'obese' and 'non-obese' adults.

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Obese adults had WC ≥102 cm for men or WC ≥ 88 cm for women. Non-obese adults were those with WC < 102 cm for men or WC < 88 cm for women.

Subjects and methods

The present study utilized data from the Third National Health and Nutrition Examination Survey (NHANES III). NHANES III collected health and nutritional information from non-institutionalized US citizens over the age of 2 months. Standardized interviews were done in the subjects' homes and physical examinations were carried out in a mobile examination centre (MEC). The number of sample persons for the survey was 39 695, with 33 994 of these individuals interviewed and 30 818 both interviewed and examined[19]. NHANES III participants aged 20 years and above were included in the present study; approximately half of those both examined and interviewed in NHANES III (*n* 15 658) were included. Pregnant women and adults with missing data for HEI or WC were excluded from the present analysis. Based on the variables included in a specific analysis run, participants with missing data values for covariates were further excluded.

Key variables for analysis were collected during the examination portion of the survey. The HEI dietary data were collected using a 24 h recall taken during an examination in the MEC and were provided in the HEI data file[20]. The 1995 HEI was developed by the US Department of Agriculture to measure overall quality of the diet and has a range from 0 to 100. The total HEI score is calculated based on meeting recommendations of the Food Guide Pyramid, as well as for total fat, saturated fat, sodium, cholesterol and variety. Each of the ten HEI component scores contributes from 0 to 10 points to the total HEI score[20]. The ten HEI component scores include the following dietary measures: (i) dairy; (ii) fruit; (iii) grain; (iv) meat; (v) vegetables; (vi) total fat; (vii) saturated fat; (viii) sodium; (ix) cholesterol; and (x) variety.

Methods for calculating HEI scores from dietary intake reported during the 24 h recall are reported elsewhere[20]. WC was used to evaluate weight status and measure abdominal adiposity[21]. Trained technicians took WC measures during the examination portion of NHANES III. These measures were conducted in the MEC[22]. Abdominal obesity was defined as WC ≥ 102 cm for men or WC ≥ 88 cm for women[23,24]. Two categories were created, abdominal obesity (1) and non-obese (2), based on this measure of abdominal adiposity.

Logistic regression models were performed to study the relationships between HEI scores and abdominal adiposity. The following covariates were included in the regression analyses: age (years), sex (1 = male, 2 = female), ethnicity (1 = non-Hispanic white, 2 = non-Hispanic black, 3 = Mexican American, 4 = other), residence location (1 = urban, 2 = rural), income (poverty:income ratio), education (years), smoking (1 = current smoker, 2 = not a current smoker), activity (total moderate and vigorous sessions/week), marital status (1 = married, spouse in household, 2 = married, spouse not in household, 3 = living as married, 4 = widowed, 5 = divorced, 6 = separated, 7 = never married), energy intake (kilojoules) and alcohol intake (grams).

Two types of sample weight must be used when analysing NHANES III data, including a full sample weight and multiple replicate weights. The first type of sample weight makes adjustments for probability of selection, non-response, the inadequacies of the sampling frame, and disparities between the sample and the US population. The full sample weight was the exam sample weight, WTPFEX6 (variable name). The second type of sample weight is replicate weights, which accounts for variance in the sample. The National Center for Health Statistics calculated these replicate weights using Fay's method[19]. Fay's weights used in the present analysis included WTPXRP1 (variable name) to WTPXRP52 (variable name), which were fifty-two individual, replicate weights.

Microsoft® Office Access (2003; Microsoft Corp., Redmond, WA, USA) was used to import data and run queries to limit data to those subjects who met the inclusion criteria: age 20 years and older and non-pregnant. WesVar 3·0S software (Westat Inc., Rockvile, MD, USA) was used to recode data and run all regression and table analyses. WesVar is appropriate for use with complex study designs such as the stratified, multi-stage probability sample employed by NHANES III. Means and standard errors were calculated using the WesVar table analysis, and logistic regression models were run using the WesVar regression analysis.

Two separate logistic regression analyses were run for total HEI (regression model 1) and the HEI components combined (regression model 2). Regression model 1 was defined as the following: abdominal adiposity category (dependent variable) and total HEI score, age, sex, ethnicity, residence location, income, education, smoking, activity, marital status, energy intake and alcohol intake (independent variables). Regression model 2 was defined as the following: abdominal adiposity category (dependent variable) and HEI dairy score, HEI fruit score, HEI grain score, HEI meat score, HEI vegetable score, HEI fat score, HEI saturated fat score, HEI cholesterol score, HEI sodium score, HEI variety score, age, sex, ethnicity, residence location, income, education, smoking, activity, marital status, energy intake and alcohol intake (independent variables).

Results

Descriptive data for the study population are presented in Table 1. The sample size for the present study was 15 658, with approximately 48 % men and 52 % women. The study included men and non-pregnant women 20 years of age and older, with an average age of 45 years. The mean

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Table 1 Descriptive statistics of the sample: US adults, men and non-pregnant women, aged 20 years and above, Third National Health and Nutrition Examination Survey

	Unweighted *n*	Weighted mean	SE
Total HEI score	15 658	63·72	0·220
WC (cm)	14 950	91·90	0·203
Age (years)	15 658	44·95	0·071
Education (years)	15 556	12·34	0·067
Physical activity (frequency/week)	15 595	5·91	0·140
Poverty:income ratio	14 207	3·09	0·050
	Unweighted *n*	**Weighted %**	**SE**
Participants			
Men	7470	48·31	0·109
Women	8188	51·69	0·109
Age group (years)			
20–29	3191	21·43	0·173
30–39	3147	23·95	0·157
40–49	2495	19·12	0·113
50–59	1786	12·61	0·097
60–69	2208	11·54	0·060
70+	2831	11·35	0·082
Ethnicity			
Non-Hispanic white	6478	76·53	0·867
Non-Hispanic black	4362	10·81	0·065
Mexican-American	4201	5·00	0·026
Other	617	7·66	0·865
Current smokers	4084	28·47	0·734
Demographics			
Metro (urban)	7616	47·97	3·623
All other areas (rural)	8042	52·03	3·623
Marital status			
Married – spouse in household	8710	60·74	0·807
Married – spouse not in household	302	1·35	0·132
Living as married	615	3·82	0·265
Widowed	1673	7·22	0·186
Divorced	1206	8·35	0·347
Separated	585	2·55	0·153
Never married	2538	15·99	0·647

HEI, Healthy Eating Index; WC, waist circumference.
Means, percentages and standard errors were weighted to represent US adults. Table analysis was employed to calculate means, percentages and standard errors.

Table 2 Sample size and estimated percentage of the US population by WC category: US adults, men and non-pregnant women, aged 20 years and above, Third National Health and Nutrition Examination Survey

	Men and women combined			Women			Men		
WC category	*n*	Weighted %	SE	*n*	Weighted %	SE	*n*	Weighted %	SE
Non-obese	8501	62·3	0·60	3435	53·3	0·87	5066	72·0	0·70
Abdominal obesity	6449	37·7	0·60	4364	46·7	0·87	2085	28·0	0·70

WC, waist circumference.
WC categories: non-obese, WC < 102 cm for men and WC < 88 cm for women; abdominal obesity, WC ≥ 102 cm for men and WC ≥ 88 cm for women.
Percentages and standard errors were weighted to represent US adults. Table analysis was employed to calculate percentages and standard errors.

total HEI score was 63·7 on a scale from 0 to 100 points. The mean BMI was 26·5 kg/m^2, which falls into the overweight category. The mean WC was approximately 92 cm, which would indicate abdominal obesity for women but not men. According to results presented in Table 2, 37·7 % (SE 0·60) of the sample had abdominal obesity. More women than men had abdominal obesity, with nearly half of females meeting or exceeding the criterion for abdominal obesity, i.e. WC ≥ 88 cm.

Mean HEI scores by WC category are shown in Table 3. HEI component scores varied between non-obese and abdominal obese groups, while mean total HEI score did not differ between WC groups. For women, the sodium score was higher and the dairy, total fat and variety scores were lower for the obese group. For men, the vegetable score was higher and the total fat and saturated fat scores were lower for the abdominally obese group compared with the non-obese group.

Results of logistic regression analyses are presented in Table 4. Relative risks of abdominal obesity per unit increase in total HEI score (model 1) and HEI component scores (model 2) were analysed. The odds ratio for a 1-point

Table 3 Mean total HEI score and HEI component scores by WC category and gender: US adults, men and non-pregnant women, aged 20 years and above, Third National Health and Nutrition Examination Survey

	Women					Men				
	Non-obese (*n* 3435)		Abdominal obesity (*n* 4364)			Non-obese (*n* 5066)		Abdominal obesity (*n* 2085)		
	Mean	SE	Mean	SE	*P* value	Mean	SE	Mean	SE	*P* value
Total HEI score	65·1	0·31	64·7	0·27	NS	62·6	0·37	62·0	0·55	NS
HEI component scores										
Dairy	6·17	0·07	5·80	0·07	0·0002	6·72	0·07	6·92	0·09	NS
Fruit	4·07	0·09	4·03	0·10	NS	3·25	0·11	3·43	0·16	NS
Grain	6·25	0·07	6·20	0·06	NS	6·92	0·07	6·75	0·09	NS
Meat	6·37	0·07	6·56	0·08	NS	7·71	0·06	7·64	0·09	NS
Vegetables	6·03	0·07	6·11	0·06	NS	6·04	0·09	6·31	0·09	0·0330
Cholesterol	8·37	0·09	8·42	0·07	NS	6·66	0·11	6·64	0·16	NS
Fat	6·63	0·07	6·40	0·08	0·0023	6·49	0·12	5·89	0·14	0·0002
Saturated fat	6·52	0·08	6·42	0·08	NS	6·45	0·09	5·83	0·16	0·0002
Sodium	7·01	0·10	7·43	0·07	0·0005	4·37	0·09	4·64	0·13	NS
Variety	7·62	0·08	7·37	0·07	0·0343	7·99	0·06	7·90	0·10	NS

HEI, Healthy Eating Index; WC, waist circumference.
Total HEI score range, 0–100; HEI component score range, 1–10.
WC categories: non-obese, WC < 102 cm for men and WC < 88 cm for women; abdominal obesity, WC ≥ 102 cm for men and WC ≥ 88 cm for women.
Means and standard errors were weighted to represent US adults. Table analysis was employed to calculate mean and standard error values. *t* Tests were run to calculate a *t* statistic and the corresponding *P* value for differences between non-obese and obese groups (NS, $P > 0.05$).

Table 4 Odds ratios of abdominal obesity per unit increase in total HEI score and HEI component scores: US adults, men and non-pregnant women, aged 20 years and above, Third National Health and Nutrition Examination Survey

	Women (*n* 7001)		Men (*n* 6476)	
Abdominal obesity risk (WC)	OR	95 % CI	OR	95 % CI
Total HEI score	0·992	0·985, 0·998	0·986	0·978, 0·993
HEI component scores				
Dairy	0·999	0·977, 1·022	1·017	0·989, 1·045
Fruit	0·974	0·956, 0·992	0·987	0·955, 1·021
Grain	1·011	0·977, 1·047	0·974	0·935, 1·014
Meat	1·034	0·998, 1·071	0·999	0·962, 1·037
Vegetables	1·010	0·989, 1·032	1·022	0·990, 1·054
Cholesterol	0·987	0·962, 1·011	0·994	0·974, 1·015
Fat	0·997	0·968, 1·026	0·989	0·956, 1·023
Saturated fat	0·990	0·960, 1·021	0·969	0·940, 0·999
Sodium	1·012	0·987, 1·038	0·983	0·952, 1·015
Variety	0·977	0·944, 1·011	0·960	0·923, 0·999

HEI, Health Eating Index; WC, waist circumference.
Abdominal obesity risk: WC ≥ 102 for men and WC ≥ 88 for women compared with men and women with lower WC measures.
Analyses were weighted to represent the US population. Logistic regression models were employed to calculate odds ratios and 95 % confidence intervals. Two separate logistic regression models were run: regression model 1 for the total HEI score and regression model 2 for the HEI component scores. Both models were adjusted for age, ethnicity, activity, residence location, income, marital status, smoking, education, energy intake and alcohol intake.

increase in total HEI score is significantly lower than 1·0 for both women and men, but does not look that much lower. This is because the HEI score range is 0–100, thus a 1-point increase in total HEI is not really a lot on a 100-point scale and that is what the calculated odds ratio is based on. For each point that total HEI score increased, the risk of abdominal obesity (WC) decreased by 1·4 % for men ($P \leq 0.001$) and by 0·8 % for women ($P = 0.014$). Thus, a 10-point increase in total HEI score would be associated with a 14 % decrease in risk of abdominal obesity for men and an 8 % decrease for women. For men, an increase of 1 point for the saturated fat score was related to a 3·1 % decrease in abdominal obesity risk ($P = 0.042$) and an increase of 1 point for the variety score was related to a 4·0 % decrease in risk ($P = 0.043$). For women, an increase of 1 point for the fruit score was related to a 2·6 % decrease in risk of abdominal obesity ($P = 0.007$). The relationship between the meat score and abdominal obesity was not significant at the 95 % confidence level ($P = 0.0615$).

Discussion

The results of the present study indicate that for a nationally representative sample of US adult men and women, overall dietary quality (i.e. total HEI score) and HEI component scores were related to abdominal adiposity. The inverse relationship between dietary quality and obesity is consistent with other studies[12–16,25–27]. However, some research studies have failed to find similar relationships[28,29].

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More women than men were categorized into the obese category based on WC. Nearly half of the women in the present study sample were abdominally obese. High rates of abdominal obesity have been reported by other studies[30,31]. This is concerning because of the relationship between abdominal obesity and chronic disease.

Gender differences were observed for relationships between food group scores and abdominal obesity. Men may benefit from increased variety and less saturated fat in their diets, while women may benefit from increased fruit intake. Further, men with higher fat scores had reduced risk of abdominal obesity. A high score is indicative of fat consumption that follows dietary recommendations, thus maintaining a fat intake below 30 % is desirable for reduced risk of abdominal obesity. A higher component score would indicate meeting recommendations or close to recommendations for a food group, nutrient or variety.

Meat intake has been associated with obesity[27,32–37]. However, the present study failed to establish a significant relationship at the 95 % confidence level. Thus the present results conflict with multiple studies reporting that higher meat intake is associated with obesity[27,32–37]. Low intakes of meats and processed meats have been associated with lower increases in BMI over time; however, further research is needed to identify foods in the meat group that are specifically related to the increased risk of both obesity and abdominal obesity among women[13]. The failure to establish a significant relationship between the meat score and abdominal obesity may be partially attributed to the limited range of meat intake observed by using the HEI score, with two to three servings corresponding to a 10-point meat score.

The present study explored the independent effect of fruit and vegetable scores on abdominal obesity risk; other studies have reported that increased fruit and vegetable intake combined, or as part of a healthful diet, has an inverse relationship to anthropometric measures[14,38–40]. An increased fruit score was associated with reduced risk of abdominal obesity for women but not men. These findings are consistent with other studies that have reported an inverse relationship between fruit and obesity[13,35,41]. The lack of findings for men in the present study may be due to the lower fruit intake among men and therefore a limited range of intake[42]. Notably, the fruit score was the lowest of all HEI component scores for a US sample[20].

Several relationships between abdominal obesity and HEI component scores varied between genders. Additional research is needed to better understand these relationships and gender differences. The recently updated HEI would provide additional information for the fruit, vegetable and grain groups, because these groups have been divided into two separate scores for each group based on the current Dietary Guidelines for Americans[43]. However, additional subgroups of these food groups as well as the meat and dairy groups would provide more specific, critical information about choices within these food groups in relation to abdominal obesity for men and women.

A higher saturated fat score was associated with reduced risk of abdominal obesity in men. A high HEI component score for this nutrient indicates that participants were meeting or close to meeting recommendations of 10 % or less of energy from total fat. Thus, high scores indicate low consumption of these nutrients and are associated with a more favourable abdominal obesity status. Studies have reported conflicting results for fat intake and obesity, with both a direct relationship[16] and no significant relationship[44]. The results presented here are an important addition to the literature reporting relationships between fat and abdominal obesity. Additional studies are needed, as some experts support a higher percentage of energy intake from total fat[45] while others support lower fat intakes[46]. Further, the updated HEI has removed total fat as a component score[43].

Dietary variety has been an important part of dietary recommendations[47,48]. Results of the present study indicate that higher dietary variety was associated with lower risk of abdominal obesity for men. These results conflict with another study reporting a direct relationship between variety and BMI that was attenuated after adjusting for energy intake[49]. The conflicting results may be partially attributed to different methods utilized to measure dietary variety. To date, there has been limited research reporting on variety in the diet and abdominal obesity.

The present study examined the relationships between total HEI and its component scores and abdominal obesity for a sample representative of the US population. HEI and obesity have previously been reported using NHANES data[15]. The current study provides new information regarding relationships between the total 1995 HEI score, the components of the 1995 HEI score, and abdominal obesity. The HEI was updated in December 2006 to reflect changes in the new Dietary Guidelines for Americans released in 2005[43]. One of the important updates to the HEI-2005 is the standardization of dietary quality for energy intake (kilojoules). Notably, our study did include energy as a covariate. Additionally, HEI scoring and subgroups have been modified with the HEI-2005 update. Some potentially important subgroups have been identified that may be associated with reduced risk for abdominal obesity including whole grains, healthy oils, legumes, whole fruits, and dark green and orange vegetables. Future research analysing the relationships between abdominal adiposity and the new HEI-2005 and component scores is needed.

The results of the present observational study should be interpreted with caution. The dietary data were self-reported and specific foods and food groups were not differentiated within food groups. Further, separate abdominal obesity criteria have been established for Asians (≥90 cm for men and ≥80 cm for women), and this sub-sample was not separated for the present analysis[23].

Alternatively, the current study provides valuable information about the relationships between diet and abdominal obesity in terms of overall dietary quality, food groups, key nutrients and dietary variety for a sample representative of the US adult population.

In summary, multiple dietary interventions aim to improve dietary quality[47,48,50]. The present findings provide evidence for a lower risk of abdominal obesity with higher overall dietary quality. Further, recommendations for increased fruit intake for women and reduced saturated fat intake and greater dietary variety for men may be particularly beneficial goals to reduce abdominal obesity risk. The findings of the present study indicate that not only dietary quality, but also specific components of the HEI score may have beneficial effects on weight status. By improving dietary quality, a more favourable WC status may be obtained.

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