MACRONUTRIENTS AND WAIST CIRCUMFERENCE COMPARED TO HIP CIRCUMFERENCE

A Thesis
by
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Abstract

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Introduction: A large waist circumference (WC) has more detrimental health outcomes than a large hip circumference (HC). Macronutrient calorie distribution affects the health of individuals. Quantity and quality of macronutrients may play a major role in WC and HC over time. The purpose of this study is to investigate the effects of the quality and quantity of macronutrients on WC and HC.

Methods: Participants (*N=11,343*) were from the Atherosclerosis Risk in Community Study. Those diagnosed with cancer or with a decrease in WC or HC of 15 cm or more over six years were excluded. Change scores were created for anthropometrics between visits over six years. Macronutrient intakes were assessed by a food frequency questionnaire at the first visit. Linear regressions were performed with quartiles of dietary components on change scores for WC and HC with controlling factors. Subgroup analysis was performed by gender.

Results: WC decreased in higher quartiles of intakes of total carbohydrates, dietary fiber and fructose ($p<0.005$). WC increased in higher quartiles of sucrose, total protein, animal protein and alcohol ($p<0.02$). Higher quartiles of intakes of total carbohydrate, sucrose, fructose, animal protein, and vegetable fat were associated with decreased HC ($p<0.05$). Higher quartiles of animal fat, total fat, and total protein were associated with increased HC ($p<0.05$). In males, WC and HC were associated with fructose, sucrose, total fat, and total protein. In females, WC and HC were associated with dietary fiber, fructose, alcohol, animal protein, total protein, animal fat, and vegetable fat.

Conclusion: Macronutrients based on quality and quantity play a significant role in the distribution of adiposity of individuals and may affect WC and HC.

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Foreword

Chapter 2 of this thesis will be submitted to *Nutrition Research,* a peer-reviewed journal published by Elsevier; it has been formatted according to the style guide for that journal.

Chapter 1: Introduction

Obesity is defined medically as "a state of increased adipose tissue of sufficient magnitude to produce adverse health consequences and is associated with increased morbidity and mortality".[1] Obesity rates are increasing rapidly throughout the world, leading to an increase of diseases such as diabetes, cardiovascular disease (CVD), kidney disease, and metabolic syndrome (MetS). The increasing numbers of these different diseases and syndromes as well as the increasing prevalence of obesity indicate a need to find ways to treat and prevent these diseases from occurring. Increased adipose tissue could increase diabetes, cardiovascular disease, liver problems and some forms of cancer.[1] If these numbers continue to increase, health care costs will continue to rise and become a greater social issue. Identifying and promoting measurements to help monitor these diseases and predictors may help.

Anthropometrics are a way to measure obesity and can indicate where on the body the adiposity occurs. Increased disease rates indicate a need for better use of anthropometric measures. Anthropometric measures are studied to determine risk of obesity-related diseases. Body mass index (BMI), percent body fat (%BF), waist circumference (WC), hip circumference (HC), and waist-to-hip ratio (WHR) are measurements that have been shown to be good predictive indicators. BMI was not as effective as other measurements in predicting specific diseases but may indicate risk for total mortality.[2] Percent BF was shown to be positively related to blood pressure, triglyceride levels, insulin resistance, and increased C-reactive protein but not fasting glucose levels in individuals with a normal BMI.[3]

According to Gomez-Ambrosi *et al.* %BF is a better indicator for prediabetes and type 2 diabetes in males with a BMI <25 and over the age of 40 than is WC or BMI.[1] A large WC has been shown to be predictive of diabetes, coronary heart disease (CHD), myocardial infarction (MI), MetS, cancer risk, and all-cause mortality and can be a more accurate indicator of adipose obesity than BMI and %BF.[4-8] Reports on a large HC seem to show mixed results of being protective and increasing risk. Research on HC has shown an independent inverse risk for MI, CVD and diabetes.[9] Research has also shown that the best predictive results for chronic diseases were found when accounting for BMI, WC, and HC.[10,11] Combining measurements and including BMI may be the best method to use as predictive indicators.

Macronutrients comprise a major component of the diet of any individual and include carbohydrates, fats, and proteins. The distribution of the calories consumed can affect the weight and health of an individual. Different studies have shown that diet can affect weight and WC, but few studies have shown a change in HC with respect to diet.[7,12,13-22] A review found that the quality of the food may play a larger role in HC than differences between macronutrients.[12] More research needs to be done to study the effects of quality and type of macronutrients on waist and hip circumference.

Literature Review

Anthropometry and Chronic Diseases

According to the Center for Disease Control, obesity has a prevalence of 34.9% throughout the United States.[23] This high prevalence of obesity is leading to other chronic diseases. The prevalence of heart disease in the United States is 11.5%.[24] The rate of diabetes has increased by 160% since 1980 and is 9.1% of the population [25] with 11.7% aged 45-64.[26] Cerebrovascular disease has a prevalence of 2.7%,[27] and kidney disease 1.9%.[28] MetS is increasing in prevalence and is an indicator of risk of different chronic diseases.[29,30] In 2006, MetS affected almost 50% of individuals aged 50 or older in the U.S. and in 2009 34% of individuals aged 20 or older.[29] Increased adipose tissue has been shown to indicate a risk for different chronic diseases.[1] Adipose tissue can be measured through anthropometric measurements such as WHR, BMI, WC, and HC and these different measures can therefore help in predicting risk for different chronic diseases.

WHR is an anthropometric measure of adiposity but is not commonly used currently in practice. Rheaume *et al.* showed a stronger association between WHR and stroke than between BMI and stroke and found that high WHR was associated with increased systolic and diastolic blood pressure.[31] Lissner *et al.* found in females a high association for risk of CVD and all-cause mortality with a high WHR.[9] Cameron et al. found contradictory results. The investigators found that WC and HC were superior measurements to WHR and improved risk assessments of outcomes of most if not all associations in determining chronic disease.[11]

BMI is an anthropometric measure that compares height to weight and categorizes weight independent of height. Categories of BMI include: underweight (<18.5), normal

(18.5-24.9), overweight (25.0-29.5), and obese (> 30.0). A study looking at BMI, WC, and the association with coronary heart disease (CHD) showed that men with a BMI 23-24.9 had a relative risk (RR) of 1.22 of developing CHD compared to individuals with a BMI 18.5-22.9, whereas individuals with overweight and obese BMIs had a RR of 1.71, and 1.81, respectively. Women in the same categories showed a RR of 1.1, 1.53, and 2.16, respectively.[8] A review by Czernichow *et al.* showed that a higher BMI may protect against total mortality but was not related to cardiovascular death, whereas WC or WHR did show an association with cardiovascular death and increased central adipose tissue. There was also seen an increased the risk of mortality.[32]

Waist circumference can be used as an indicator for chronic disease risk. A large WC can lead to higher diagnoses of chronic and vascular diseases. Dallongeville *et al.* found this to be the case among younger populations, Caucasians, and former smokers. The researchers also found that individuals with a large WC have a more difficult time achieving target blood pressure, triglyceride levels, and blood sugar.[32] Many researchers have found that a large WC is predictive for diabetes, CHD, MI, MetS, insulin resistance syndrome, cancer, hypertension (HTN), coronary artery disease, dyslipidemias, all-cause mortality and as a result, increased medical care costs.[4,5,33-36] The NHANES III study indicated that high WC with a normal BMI was found in 14% of women and 1% of men. The World Health Organization (WHO) found that 10% of individuals with a BMI less than 30 have a WC greater than the recommended cut off points of 35 inches (88.9 centimeters) for women and 40 inches (101.6 centimeters) for men.[4,37] It was also found that 70% of women and 25% of men with a BMI greater than 30 had WC greater than the cut off points.[4,38] Researchers have investigated predictors for disease by gender and have found varying results. Siren *et al* indicated that a WC greater than 94 centimeters in men predicted an increased risk for developing type 2 diabetes.[39] Other researchers found that WC was a predictor for vascular disease in women, but BMI was a better indicator in men.[40]

HC is a measurement that may indicate the opposite effect of WC and could be protective or predictive of different diseases. Research has shown that the larger the HC the lower the risk of developing type 2 diabetes and the better glucose is metabolized.[41,42] In contrast, Jialal *et al.* investigated the secretion of different hormones and found that gluteal fat around the hips may secrete hormones that increase the risk for developing diabetes and cardiovascular disease in individuals with MetS and a larger HC.[43] Throughout the research literature, gender differences and predicting risk of disease were seen more with HC. Parker *et al.* studied the association between HC, diabetes, and CHD in both men and women. After adjusting for BMI and WC the incidence of diabetes and CHD decreased with a larger HC.[44] According to Cameron *et al.* a narrow HC was a strong risk predictor for metabolic disease and premature death.[11] Women with wide hips had a decreased risk of developing CVD by 45%, CHD by 51% and total mortality by 87%, whereas no association was seen with men.[10] Lissner *et al.* showed that women with the highest HC had a lower prevalence of diabetes, MI, and CVD when compared to the lowest HC while controlling for BMI.[9] Heitmann *et al.* found that the size of a women's HC was a better indicator of development of CVD, CHD and total death, and that BMI and size of WC were better indicators in men.[10]

Some studies examined the combined effect of WC and HC on the prediction of disease. The EPIC study found that, when both WC and HC were included, the accuracy in prediction of heart disease increased 10 – 18%.[31] Identifying diabetes was also improved when including both WC and HC.[11]

Macronutrients and Anthropometry

Macronutrients are the major component of the diet of an individual and include carbohydrates, fats and proteins. Studies have shown that the distribution of calories among these macronutrients can affect the weight and health of an individual. Researchers have shown varying results in regards to carbohydrate, protein and fat diets and the effects on weight distribution.

When investigating varying levels of carbohydrate intake, researchers have found different results. Baer *et al.* studied the difference between supplementing whey or soy protein and supplementing carbohydrates. The researchers found, after six months of supplementation, body weight and fat mass decreased in individuals who were overweight and obese in the groups that were supplemented with whey or soy protein but not in the group supplemented with carbohydrates. No difference was seen between supplementation with soy or whey protein.[13] Jenkins *et al.* studied high and low carbohydrate diets and indicated there was no difference in the weight loss. There was an increase in cholesterol in the low carbohydrate group.[12] Claessens *et al.* found that WC increased with a high carbohydrate diet.[19] Romaguera found that with an increased carbohydrate intake, WC decreased after adjusting for BMI. The researcher also found that a decrease in WC was noted with a higher intake of fiber and alcohol. The researcher also found that a high-energy dense, high glycemic index and load diet increased WC.[7] Another study indicated a low glycemic load diet reduced WC and increased WHR.[20] Rossi *et al.* showed in women a small association of a decrease in WHR as glycemic index and glycemic load increased.[45] According to Tonstad *et al.* high dietary fiber intake was associated with a significant reduction in WC.[7] Halkjaer *et al.* found that as women increased their intake of fruits and vegetables, WC decreased, but as simple sugars increased WC increased. [21]

The intake of protein, fat and alcohol showed differing results among researchers. Atkins-like diets with a low carbohydrate intake and high fat and protein intake have led to weight loss that is associated with lower triglycerides, higher HDL, and LDL cholesterols, lowered glycated hemoglobin, fasting insulin, and blood glucose, but these decreases were not sustained after one year.[12] Soenen found that both a high and normal protein diet resulted in a decrease in body weight, BMI, fat mass, %BF, and WHR.[15] Additionally, Tonstad *et al.* found that obese individuals who consumed diets high in beans had improved lipid levels.[37] Claessens *et al.* found that with a high protein diet WC decreased significantly.[19] Halkjaer *et al.* found a significant inverse association between WC with intake of protein and WC. Specifically, animal protein intake decreased WC in both men and women.[21] Brandhagen *et al.* found that protein intake in men was associated with a higher BMI, %BF, and WC.[22] The Mediterranean diet was studied with varying amounts of monounsaturated fatty acids (MUFA) and the effect on weight loss. High intake of MUFA helped individuals maintain weight loss, improved insulin resistance and improved ratio of LDL to HDL cholesterol. Tonstad *et al.* found that trans fat was related to a higher WC, but total fat was not. Brandhagen *et al.* found that increased fat intake was associated with a lower BMI and WC in men.[22] Halkjaer *et al.* found that vegetable fat increased WC but animal fat did not.[21]

Alcohol is a substance that provides calories and can therefore contribute to body weight. Brandhagen *et al.* studied alcohol consumption. In men alcohol consumption was related to higher fat in the abdomen. In women, general body fat composition decreased with the consumption of alcohol.[22] Romaguera also found a decrease in WC with an intake of alcohol for both men and women.[13]

Research by Chiuve *et al*. and Jenkins *et al.* is the only reported literature to indicate that nutritional quality or origin of the food, whether it came from an animal or plant source, played a role in WC and HC measures, and thus affect the risk of chronic disease and total mortality.[12,14] Therefore, the purpose of this study was to investigate the effects of the quality and quantity of macronutrients on WC and HC as a way to prevent diseases through diet specific to individuals' measurements and risk factors. The proposed research hypotheses are that intake of protein and fat from animals will differ in effect on WC and HC from intake of protein and fat from plants. Also, carbohydrates, fiber and alcohol will affect WC and HC differently by gender.

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Chapter 2: Article

Macronutrients and Waist Circumference Compared to Hip Circumference

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List of Abbreviations

WC; Waist Circumference

HC; Hip Circumference

WHR; Waist to Hip Ratio

MetS; Metabolic Syndrome

CVD; Cardiovascular Disease

BMI; Body Mass Index

%BF; Percent Body Fat

FFQ; Food Frequency Questionnaire

ARIC; Atherosclerotic Risk in Communities

kJ; kilojoule

Abstract

Introduction: A large waist circumference (WC) has more detrimental health outcomes than a large hip circumference (HC). Macronutrient energy distribution affects an individual's health. Quantity and quality of macronutrients may play major roles in WC and HC. This study's purpose is to investigate the effects of quality and quantity of macronutrients on WC and HC.

Methods: Participants (N=11,343) were from the Atherosclerosis Risk in Community Study. Those diagnosed with cancer or a decrease in WC or HC of 15 cm or more over six years were excluded. Change scores were created for anthropometrics between visits over six years. Macronutrient intakes were assessed by a food frequency questionnaire at visit one. Linear regressions were performed with quartiles of dietary components on change scores for WC and HC with controlling cofactors. Subgroup analysis was performed by gender.

Results: WC decreased in higher quartiles of total carbohydrates, dietary fiber, and fructose ($p<0.005$). WC increased in higher quartiles of sucrose, total protein, animal protein, and alcohol ($p<0.02$). Higher quartiles of total carbohydrate, sucrose, fructose, animal protein, and vegetable fat were associated with lower HC ($p<0.05$). Higher quartiles of animal fat, total fat, and total protein were associated with higher HC ($p<0.05$). In males, WC and HC were associated with fructose, sucrose, total fat, and total protein. In females, WC and HC were associated with dietary fiber, fructose, alcohol, animal protein, total protein, animal fat, and vegetable fat.

Conclusion: Macronutrient quality and quantity play a significant role in individuals' adiposity and affect WC and HC.

Keywords: macronutrients, waist circumference, hip circumference, body composition, diet

1. Introduction

Obesity has been defined as “a state of increased adipose tissue of sufficient magnitude to produce adverse health consequences and is associated with increased morbidity and mortality” [1]. The prevalence of obesity is quickly growing throughout the world, leading to an increase of many diseases such as diabetes, cardiovascular disease (CVD), kidney disease, and metabolic syndrome (MetS) [2-8].

Anthropometric measurements are a way in which obesity can be quantified and can indicate where on the body the adiposity occurs. Anthropometric measures have also been studied to assess predictive qualities in determining risk of disease. Increased disease rates and obesity indicate a need for better use of anthropometric measures. Anthropometric measures are then used to study the use of these measures for determining risk of disease. Body mass index (BMI), percent body fat (%BF), waist circumference (WC), hip circumference (HC), and waist-to-hip ratio (WHR) are measurements that have been shown to be good predictive indicators [9-15]. A large WC has been shown to be predictive of diabetes, coronary heart disease (CHD), MetS, cancer risk and all-cause mortality and can be a more accurate indicator of adipose obesity than BMI and %BF [11-15]. A large HC may indicate protection from disease on the one hand and increased disease risk on the other [16]. Research has shown an independent inverse risk for myocardial infarction, CVD and diabetes while those with the highest HC had a lower prevalence of diabetes, myocardial infarction and CVD [16].

Macronutrients make up a major component of any individual's diet and include carbohydrates, fats and proteins. The distribution of the energy consumed among the macronutrients can affect the weight and health of an individual. Different studies have shown that diet can affect weight and WC, but few studies have shown a change in HC with respect to diet [14, 17-19]. Varying intakes of carbohydrates affect body composition differently. Claessens *et al*, indicated WC increased with a high carbohydrate diet while Romaguera found a weak inverse association with carbohydrates and a decreased WC with a higher intake of fiber [19, 20]. Other research reported an increased intake of fruits and vegetables decreased WC, while simple sugars increased WC [22]. Protein intake affected an increase in WC with an increase of animal protein consumed and Brandhagen *et al*. found that protein intake in men was associated with a higher WC [22, 23]. The effect of fat intake on WC depended on the source. Vegetable fat increased WC but animal fat had no effect [23]. Alcohol is another substance that provides energy. Research showed that alcohol consumption is related to higher abdominal fat in men and a decreased general body fat composition in women [23]. A review by Jenkins found that the quality or source of the food may play a larger role in body composition than differences between macronutrients [24].

There are still unanswered questions about the effects of quality and quantity of macronutrients on waist and hip circumference. The immediate need for solutions to decrease obesity and its numerous comorbidities is critical. The purpose of this study was to investigate the effects of the quality and quantity of macronutrients on WC and HC and therefore overall body composition. The proposed hypothesis is that increase in dietary fiber will decrease WC and increase HC and that an intake of vegetable fat and animal protein increase WC and HC more in males than females.

2. Methods and Materials

The study population was from the Atherosclerosis Risk in Communities (ARIC) Study. This manuscript was prepared using ARIC research materials obtained from the National Heart Lung Blood Institute (NHLBI) Biologic Specimen and Data Repository Information Coordinating Center and does not necessarily reflect the opinions or views of the ARIC research groups or the NHLBI. The Institutional Review Board of Appalachian State University approved acquisition of this dataset. Details of the methodology of the ARIC study are described elsewhere [9]. ARIC was a prospective epidemiologic study to investigate atherosclerosis and cardiovascular risk factors in individuals 45-64 in four U.S. communities from 1987-1998. Data were collected at four different times: 1987-89 (visit 1), 1990-92 (visit 2), 1993-95 (visit 3), and 1996-98 (visit 4) [9]. Dietary data were collected through a food frequency questionnaire (FFQ) during visit 1. The FFQ was designed by Willet and administered in a personal interview [26]. The different types of foods included: dairy, fruits, vegetables, meats, sweets, baked goods, cereals, miscellaneous, and beverages [25]. The FFQ was then combined and the intake of 65 daily nutrients was calculated [26].

Data sets were combined and included age, sex, ethnicity, smoking status, physical activity, dietary, and nutrient intakes from visit 1, anthropometrics from visit 1 and 3, family history, and lab values. Physical activity was derived by combining three measures: work, sports, and leisure activity and placed into quartiles of overall activity. The changes in WC and HC from visit 1 to visit 3 were calculated. Percent of total energy from total carbohydrates, sucrose, fructose, vegetable fat, animal fat, total fat, animal protein, non-animal protein, total protein, alcohol, and grams of fiber per 1000 kcal were assessed. A percent of total energy was created for non-animal protein by subtracting grams of animal protein from total protein, multiplied by four and divided by total energy calories. A percent of total energy was created for animal protein by multiplying animal protein in grams by four and dividing by total energy. Likewise, a percent of total energy was created for sucrose and fructose by multiplying grams by four and dividing by total energy. Interaction variables were created to compare gender with dietary variables. Dietary intake variables were assessed by quartiles of the total population included. Quartiles were created by dividing the study population into equal quarters by each dietary variable from lowest to highest. Interaction variables were created to compare gender with quartiles of dietary variables.

Statistical analysis was performed using SPSS v20. Individuals were excluded if they had ever been diagnosed with cancer at visit 1 or 3 to prevent including individuals with extreme wasting. Individuals were also excluded if they had a WC or HC decrease of more than 15 cm during time of study. WC and HC were measured in cm. Linear regressions were performed on the changes for WC and HC with dietary variable quartiles. The linear regressions were controlled for age, gender, ethnicity, physical activity, smoking status (current cigarette smoker vs. not a current cigarette smoker), education level (3 levels), total energy, and change in BMI from visit 1 to visit 3. Subgroup analysis was performed by gender.

3. Results

Individuals in the study were 55% females, 24% Blacks (Table 1). Table 2 displays the dietary variables by quartile of intake. WC increase through follow up was significantly correlated with an increased intake of sucrose and with a decreased intake of total carbohydrates, fiber, and fructose (Table 3). HC increase through follow up was significantly correlated with an increased intake of animal fat and total protein and a decreased intake of sucrose, animal protein, and vegetable fat (Table 4).

In males, with increased intake of fructose and sucrose, WC decreased and as total fat and protein intake increased HC increased (Table 5 and Table 6). In females, as dietary fiber and fructose increased, WC decreased and as alcohol, animal protein, total protein, and animal fat increased, WC increased. With an increased intake in total carbohydrates, sucrose, and vegetable fat there was a decrease in HC in females. HC in females increased with an increased intake of animal protein, total protein, and animal fat (Table 5 and Table 6). The interaction terms showed no significant interactions between gender and WC and dietary variables. There was significant interaction seen between gender and HC with vegetable fat and animal protein (Table 5 and Table 6).

Table 1

Descriptive Statistics of Study Population and Total Energy by Gender

N= 11343	Mean ± SD Male	Mean ± SD Female
Age (years)	54±6	54±6
Gender	5418 (45%)	6594 (55%)
Black	5925 (52%)	4749 (42%)
WC (cm)	99.1±10.5	94.7±15.2
HC (cm)	102.8±7.5	105.8±11.3
Change in WC (cm) over 6 years	2.85±5.0	5.0±7.2
Change in HC (cm) over 6 years	1.61±3.8	3.0±5.2
Energy (kJ)	1791±646	1493±534

SD – Standard Deviation
WC – Waist Circumference
HC- Hip Circumference

Table 2

Quartiles of Dietary Components by %Energy

Macronutrients (% energy)	**Quartile 1**	**Quartile 2**	**Quartile 3**	**Quartile 4**
Total Carbohydrates	43.54	48.05	50.31	53.52
Dietary Fiber (g/1000kJ)	6.44	9.28	11.71	16.59
Sucrose	0.06	0.10	0.14	0.21
Fructose	0.03	0.05	0.07	0.11
Total Fat	27.60	32.19	34.56	37.20
Vegetable Fat	8.19	11.83	14.30	17.78
Animal Fat	14.48	18.79	21.64	24.53
Total Protein	15.99	17.68	18.52	19.51
Non-animal Protein	3.01	3.95	4.69	6.11
Animal Protein	8.50	11.94	14.52	18.99
Alcohol	0.00	0.00	1.69	9.16

Table 3

Macronutrients and Change in Waist Circumference Over 6 Years

Macronutrients	**Quartile 1**	**Quartile 2**	**Quartile 3**	**Quartile 4**	**Beta**	**P values for trend**
Total Carbohydrates	4.60	4.13	4.04	3.54	-0.030	0.004
Dietary Fiber	3.74	4.11	4.16	4.30	-0.111	0.003
Sucrose	4.20	4.18	4.15	3.79	0.001	0.003
Fructose	4.11	4.05	4.19	3.96	-0.028	< 0.001
Total Fat	4.52	4.22	4.01	3.56	0.012	0.232
Vegetable Fat	4.46	4.24	3.92	3.69	0.014	0.101
Animal Fat	4.41	4.26	4.11	3.52	0.014	0.097
Total Protein	4.22	3.99	4.03	4.0	0.022	0.016
Non-animal Protein	3.83	4.20	4.19	4.09	0.000	0.986
Animal Protein	3.52	3.95	3.92	4.92	0.016	0.014
Alcohol	-	4.24	4.13	3.69	0.016	0.014

Betas and p-values for trend are the result of linear regression of the change in waist circumference over six years and quartiles of each of the dietary variables controlling for age, gender, ethnicity, physical activity, smoking status (current cigarette smoker vs. not a current cigarette smoker), educational level (3 levels), total energy, and change in BMI from visit 1 to visit 3.

Table 4

Macronutrients and Change in Hip Circumference Over 6 Years

Macronutrients	**Quartile 1**	**Quartile 2**	**Quartile 3**	**Quartile 4**	**Beta**	**P values for Trend**
Total Carbohydrates	2.73	2.40	2.37	2.05	-0.020	0.040
Dietary Fiber	2.03	2.35	2.48	2.68	0.001	0.979
Sucrose	2.71	2.46	2.38	1.99	-0.041	< 0.001
Fructose	2.38	2.42	2.36	2.39	-0.013	0.028
Total Fat	2.65	2.50	2.26	2.13	0.019	0.049
Vegetable Fat	2.85	2.41	2.11	2.18	-0.024	0.002
Animal Fat	2.57	2.47	2.37	2.14	0.035	< 0.001
Total Protein	2.38	2.33	2.37	2.47	0.042	< 0.001
Non-animal Protein	2.18	2.44	2.43	2.49	0.002	0.725
Animal Protein	1.92	2.25	2.29	3.08	-0.017	0.005
Alcohol	-	2.53	2.42	2.05	-0.003	0.599

Betas and p-values for trend are the result of linear regression of the change in waist circumference over six years and quartiles of each of the dietary variables controlling for age, gender, ethnicity, physical activity, smoking status (current cigarette smoker vs. not a current cigarette smoker), educational level (3 levels), total energy, and change in BMI from visit 1 to visit 3.

Table 5

Macronutrients and Change in Waist Circumference in Gender Over 6 Years

Macronutrients	Beta		P values for Trend		Gender Interaction P value
	Male	Female	Male	Female	
Total Carbohydrates	-0.022	-0.030	0.098	0.050	0.118
Dietary Fiber	-0.019	-0.173	0.619	0.005	0.106
Sucrose	-0.026	-0.015	0.002	0.092	0.636
Fructose	-0.024	-0.028	0.004	0.002	0.654
Total Fat	0.000	0.024	0.979	0.112	0.377
Vegetable Fat	0.002	0.023	0.826	0.052	0.741
Animal Fat	-0.006	0.028	0.562	0.022	0.822
Total Protein	0.012	0.033	0.318	0.012	0.493
Non-animal Protein	0.009	-0.003	0.286	0.720	0.404
Animal Protein	0.007	0.020	0.389	0.024	0.112
Alcohol	0.011	0.022	0.201	0.018	0.726

Betas and p-values for trend are the result of linear regression of the change in waist circumference over six years and quartiles of each of the dietary variables controlling for age, gender, ethnicity, physical activity, smoking status (current cigarette smoker vs. not a current cigarette smoker), educational level (3 levels), total energy, and change in BMI from visit 1 to visit 3. Also included was an interaction term between each dietary variable and gender.

Table 6

Macronutrients and Change in Hip Circumference in Gender Over 6 Years

Macronutrients	Beta		P values for Trend		Gender Interaction P value
	Male	Female	Male	Female	
Total Carbohydrates	0.005	-0.035	0.712	0.009	0.126
Dietary Fiber	0.039	-0.027	0.233	0.486	0.160
Sucrose	-0.033	-0.047	0.746	0.000	0.058
Fructose	-0.017	-0.009	0.061	0.250	0.587
Total Fat	0.030	0.012	0.036	0.365	0.270
Vegetable fat	0.008	-0.044	0.518	0.000	0.002
Animal Fat	0.023	0.045	0.063	0.000	0.398
Total Protein	0.032	0.048	0.016	0.000	0.814
Non-animal protein	0.000	0.005	0.960	0.532	0.866
Animal Protein	0.015	0.041	0.111	0.000	0.004
Alcohol	-0.004	-0.004	0.704	0.660	0.735

Betas and p-values for trend are the result of linear regression of the change in waist circumference over six years and quartiles of each of the dietary variables controlling for age, gender, ethnicity, physical activity, smoking status (current cigarette smoker vs. not a current cigarette smoker), educational level (3 levels), total energy, and change in BMI from visit 1 to visit 3. Also included was an interaction term between each dietary variable and gender.

4. Discussion/Conclusion

This study showed that macronutrients may affect WC and HC in different ways depending on the quality and quantity. With total carbohydrates the study showed that as intake increased WC and HC decreased in both males and females. As dietary fiber and fructose increased, WC decreased in both males and females. In females, HC decreased with an increased intake of total carbohydrates, sucrose, and fructose. There is an increase in WC and HC with higher quartiles of total protein. With an increased intake of animal protein, there was an increase in WC and a decrease in HC. Among the gender subgroups, the animal protein and HC association was observed in females only. Both vegetable fat and animal fat were associated with an increase in HC. When examined by gender, an increase in animal fat was associated with an increase in HC and WC in females only. Vegetable fat intake was associated with a decrease in HC. As alcohol intake increased WC increased.

The decrease in WC seen with total carbohydrate, fiber and fructose and the increase in WC with sucrose was reported by other researchers. Romaguera *et al*., Koh-Banerjee *et al.* and Halkjaer *et al.* found that with higher intake of carbohydrates there was a decrease in WC [14, 17, 18]. Baer *et al*. showed that as the intake of fiber increased, WC decreased [18]. Halkjaer *et al.* found an increase in sugar increased WC [22]. Individuals with a smaller WC tend to eat a higher carbohydrate diet with more complex carbohydrates and dietary fiber that may lead to a lower total energy intake. Koh-Banjeree *et al.* found that with an increase in complex carbohydrates and dietary fiber there was a decrease in WC possibly due to the increased satiety and overall lower energy diet [17]. The effect seen with the increase in quartiles of dietary fiber and decrease in WC suggests that the decrease seen in WC with higher quartiles of total carbohydrates may be attributed to the effect of the total dietary fiber intake. Individuals with smaller WC and HC possibly have a larger intake of fructose because they are eating more fruits and vegetables. Also, with an increase in fruit and vegetable intake there is an increased intake of dietary fiber. According to Halkjaer *et al.* there was an inverse relationship seen with fruits and vegetables and WC [18].

Brandhagen *et al.* showed that with an increased intake of protein there was an increase in WC in men [23]. Other investigators have found the opposite relationship of a decrease in WC with intake of protein [14, 17, 18, 20, 22]. The increase in WC and HC with increase of total protein in this report could also be explained by the lack of dietary fiber in the diet; the total amount of fiber could be decreased when the individual is increasing the total amount of protein in the diet, especially animal protein. A significant correlation of -0.07 ($p<0.001$) was seen for the intake of total protein and dietary fiber in this cohort. The protein effect on WC and HC may be explained by the food sources of the protein. Individuals who are consuming higher amounts of protein may be consuming more animal fat, which increases their intake of saturated fats and cholesterol. Claessens *et al.* found that a low fat, high protein diet maintained weight loss better than a low fat, low energy, high carbohydrate diet [20]. The high intake of animal protein, and therefore cholesterol, could affect hormone levels which, according to Jialal *et al*., could affect HC [21].

Some investigators have shown that an increase in fat intake increased WC [14, 17, 18], while others have shown the opposite [23, 27]. The current results indicated that vegetable fat and animal fat were associated with an increase in HC. Halkjaer *et al.* found that as vegetable fat intake increased WC increased [22]. Alcohol is a substance that provides energy and is metabolized in the liver. Brandhagen *et al.* found that as alcohol intake increased in men WC increased, but with women it was found that general fatness decreased [23]. Romaguera also found that WC decreased with an intake of alcohol [14]. This is in contradiction to the results we found.

The lack of significance between WC and the interaction of gender and the dietary components indicates that the effect of diet on WC is generally not significantly affected by gender. The significance observed with gender and HC and vegetable fat and animal protein may indicate that these foods replace a higher portion of a male's diet. Increased HC may be caused by changes in hormone signaling from increased intake of vegetable fat and animal protein. Jialal found that the gluteal fat around the hips may secrete hormones that could increase diabetes and CVD risk in individuals with large HC [16]. The intake of vegetable fat and animal protein may be contributing to the fat on the HC through an increase in varying hormones based on gender. Also, a significant correlation between vegetable fat and animal protein -0.348 ($p<0.001$) was found in this cohort.

There is a general lack of research on the dietary determinants of WC and HC over time, and the current status of the literature is inconclusive. The type and quality of macronutrients an individual eats may be more of a factor than the amount consumed when comparing effects on WC and HC. The confusion in research results complicates the development of dietary advice to decrease the prevalence of obesity and its resulting vascular diseases.

This study had some limitations including the use of information from an older dataset (1987-1998) and secondary data analysis which cannot demonstrate cause and effect. Advantages of this study were the large study population, the ability to control for a number of confounding variables, and the relatively long follow-up period.

In conclusion, the results of this study help explain the effect of diet on WC and HC, particularly the possibility that quality as well as quantity of macronutrients may affect these indicators of obesity, and thus chronic disease risk. The results indicate a need for further experimental research to better determine the specific effects of different macronutrients on WC and HC, and exploration of this effect among other ethnicities. This knowledge may help decrease adiposity and risk for chronic diseases.

5. Acknowledgment

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Vita

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