Food group intake and central obesity among children and adolescents in the Third National Health and Nutrition Examination Survey (NHANES III)

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Abstract

Objective: To explore mean food group intakes associated with central obesity anthropometry among children and adolescents enrolled in the Third National Health and Nutrition Examination Survey (NHANES III).
Design: Cross-sectional study.
Setting: Representative sampling of the US population (1998–2002).
Subjects: Subjects were 3761 children (5–11 years) and 1803 adolescents (12–16 years) with single 24 h dietary recalls and anthropometric measures of central body fat (waist circumference and sum of subscapular and suprailiac skinfold thicknesses).
Results: Results were controlled for confounding by age, height, race/ethnicity, Tanner stage, television viewing and parental education. In younger children, there was no relationship between central adiposity and mean intakes of dairy, fruit, vegetables or grains, while a positive association with meat intake was found among boys. In adolescent boys and girls, central body fat measures were inversely associated with mean dairy and grain intakes. Adolescent boys in the highest quartile of central adiposity consumed less fruit and fewer vegetables; those in the lowest central adiposity quartile consumed less meat. Finally, adolescents who met the criteria for central obesity (waist circumference ≥85th percentile for age and sex) reported consuming significantly less total dairy (as well as milk and cheese separately), total grains (whole and refined) and total fruit and vegetables. There was no association with meat consumption. To test the stability of these findings, the final analysis was replicated in 2541 same-aged adolescents from NHANES 1999–2002; the results were very similar.
Conclusions: These cross-sectional analyses suggest that intakes of dairy, grains and total fruits and vegetables are inversely associated with central obesity among adolescents.

Keywords
Diet
Body fat
Central obesity
Children
Adolescents

Central obesity is a key component of the metabolic syndrome[1], which is associated with increased risks of CVD and diabetes[2–4]. Intra-abdominal visceral fat is particularly reactive to lipolytic stimuli and is believed to affect glucose homeostasis through its effect on circulating adiponectin levels[5]. As central obesity is more strongly associated with visceral fat than BMI, waist circumference (WC) has been proposed as the more sensitive measure of relative CVD risk[6,7].

The metabolic syndrome has been identified in children and adolescents[8] as well as adults and appears to persist from childhood into adulthood[9]. Trends of increasing overweight[10] and central obesity[11] among children and adolescents are well documented. Some studies indicate that central adiposity among children

may be increasing independent of weight[12,13]. As a surrogate measure of central body fat, WC has been suggested as an important early marker for the development of chronic diseases[14,15] as well as a practical screening tool for identifying children at risk for metabolic syndrome[16,17].

Although some studies have considered the role of dietary patterns in the development of central obesity among adults[18–21], data related to the role of food group intake in the development of central obesity at younger ages is very limited. The US Department of Agriculture's (USDA) Food Guide Pyramid and Dietary Guidelines for Americans (issued every five years) provide food-based intake guidelines for children and adults[22]. Unfortunately, there is little direct scientific evidence to support

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specific dietary recommendations for the prevention of childhood obesity, particularly central obesity. The consumption of different amounts and types of foods may impact adiposity in a variety of direct and indirect ways. For example, different foods may impact satiety through volumetric differences, effects on gastric emptying or energy content. Other foods are theorized to affect body weight through their impact on such factors as energy metabolism or storage, lipogenesis or insulin sensitivity. The goal of the current analyses was to explore the relationship of mean food group intake and anthropometric measures of central obesity in children (aged 5–11 years) and adolescents (aged 12–16 years) using cross-sectional data from the Third National Health and Nutrition Examination Survey (NHANES III, 1988–1994).

Methods

Study population

NHANES have been conducted regularly since 1960 to assess the health and dietary status of the civilian non-institutionalized US population aged 2 months and older. The surveys randomly select subjects using a stratified, multistage probability cluster design and oversample certain groups including young children, non-Hispanic blacks and Mexican-Americans. Details of the design and sampling methods as well procedures for obtaining informed consent have been described elsewhere[23]. The current secondary analyses were conducted with the approval of the Boston University Institutional Review Board. Since dietary habits may change particularly during late adolescence, we restricted the analyses to subjects who were less than 17 years of age in order to reduce the likelihood that true changes in diet would impact the estimates of usual intake[24].

The primary analyses include subjects who were 5–16 years of age and in one of three categories of racial or ethnic origin: non-Hispanic whites, non-Hispanic blacks and Mexican-Americans. A total of 4329 children aged 5–11 years children (or their parents) and 2079 adolescents aged 12–16 years completed interviews and an examination. The number of subjects (n 99) in the other racial/ethnic groups was insufficient to provide stable estimates of association, so these subjects were excluded from the analyses as has been recommended by the NHANES III Analytic and Reporting Guidelines[25]. Subjects with dietary data designated as missing or unreliable (n 317) by the study nutritionist or with extremes of energy intake (the upper and lower 2 % of the distribution of energy intake; n 227) were excluded, as were those who were pregnant or breast-feeding (n 18), taking diabetes medication (n 8), had missing data for WC circumference (n 128) or had potential confounders of interest to the study (n 47). This resulted in a final sample size of 3761 children aged 5–11 years and 1803 adolescents

aged 12–16 years. Skinfold measurement data were missing for an additional 112 subjects who were therefore excluded from any sub-analyses related to that outcome. Similar exclusion criteria were used for the 1999–2002 NHANES study population of 12- to 16-year-olds, leaving 2541 available for the analysis.

Assessment of dietary intake

Dietary intake in both NHANES III and NHANES 1999–2002 was assessed through a single 24 h recall using an automated, microcomputer-based interview[26]. Prior to age 12, the recall was completed jointly by the subject and a proxy respondent. Dietary recalls were analysed for nutrient composition using USDA nutrient files appropriate to the time period.

Food Pyramid servings of the five major food groups (i.e. dairy, fruit, vegetables, grains and meats/other proteins) were calculated from intake of both simple foods (e.g. glass of milk) and mixed dishes (e.g. lasagne) as defined by the USDA Dietary Guidelines[27,28]. One dairy serving was defined as 1 cup of milk or yoghurt, 1·5 oz of natural cheese or 2 oz of processed cheese. A fruit serving equalled 1 medium fruit (e.g. apple, banana, orange), 1/2 cup of chopped, cooked or canned fruit, or 3/4 cup of fruit juice. Total fruit (whole or as juice) was also divided into two subgroups: (i) citrus, melons and berries; and (ii) other fruits. One vegetable serving comprised 1 cup of raw leafy vegetables, 1/2 cup of cut-up raw or cooked other vegetables, or 3/4 cup of vegetable juice. There were several vegetable subgroups including dark-green vegetables, deep-yellow vegetables, white potatoes, other starchy vegetables (including legumes), tomatoes and other vegetables. French fries were included with potatoes but the added fat from frying was counted as servings of discretionary fat (see below). A grain serving (whole and refined) was represented by 1 slice of bread, 1 cup of dry cereal, or 1/2 cup of cooked rice, pasta or cereal. Finally, the meat/protein group included all forms of meat, fish, poultry, eggs, soyabean products, nuts and seeds. For the purposes of estimating intake, servings in the meat/other protein group were expressed as ounce equivalents and included items such as 1 oz of lean meat, fish or poultry, 1/2 cup of cooked dry beans, an egg, or 2 tablespoons of peanut butter[29]. Discretionary fats referred to fat in food that is above the amount that would be expected in a lean, low-fat or fat-free form of the food.

Assessment of anthropometric measures of central obesity

WC served as the main measure of central adiposity in these analyses, while the sum of suprailiac and subscapular skinfold thicknesses served as a secondary measure. Waist measurements were taken on a horizontal line at the high point of the iliac crest. The measurement was made at minimal respiration to the nearest 0·1 cm. Skinfold thickness measurements were taken using a

Holtain skinfold calliper following a standard protocol and recorded to the nearest 0·1 mm. For NHANES 1999–2002, only WC was examined as an outcome (the sum of the two skinfolds was not available).

Assessment of potential confounders

Parental education (classified as less than high school, high school and more than high school) was used as an indicator of socio-economic status (SES). Income was assessed as a secondary measure of SES in these analyses using a dichotomous classification of <$20 000 v. $20 000 or more (since nearly 10 % of NHANES III subjects failed to provide more precise data on annual income). In the NHANES III sample, parental education was retained in the final models as it confounded the main results. Since this variable was not available in the 1999–2002 surveys, parental income was used instead. The three categories of race/ethnicity as defined by NHANES included non-Hispanic blacks, Hispanic (specifically Mexican-American) and non-Hispanic whites.

Pubertal development was assessed during the physical examination by physicians who were given standardized training in the use of Tanner stage classification[30,31]. For the purpose of the present analyses, the original 5-stage Tanner scale was collapsed into three categories: (i) stage 1 or 2; (ii) stage 3; and (iii) stage 4 or 5. Tanner stage classification was not available for NHANES 1999–2002. Television watching was assessed in both surveys by questioning the child (or parent, depending on age) about the number of hours of television watched the previous day. Weight and standing height were measured according to a standardized protocol and BMI was calculated as weight in kilograms divided by the square of height in metres (kg/m^2).

Physical activity was assessed among children aged 8 years and above by questionnaire. We examined it as a potential confounder in the models for adolescents but later dropped it as it led to no change in the results.

Statistical methods

Given the cross-sectional study design, both the anthropometry measures and the dietary intakes were measured at the same time. In these analyses, we examined the adjusted mean dietary intakes associated with age- and sex-specific quartiles of WC (and the sum of subscapular and suprailiac skinfold measures). The adjusted mean level of intake in each quartile of central body fat was estimated using analysis of covariance modelling with PROC GLM in the SAS statistical software package version 9·1 (SAS Institute Inc., Cary, NC, USA).

In addition to the use of quartiles for categorizing the distributions of central adiposity, we also examined the association between the mean intakes in each of the five major food groups and related subgroups and the prevalence of central obesity. Since there are no specific cut-off points for defining an abnormal waist size in children,

we chose to explore both the 85th and the 90th age- and sex-specific percentiles. Although the 90th percentile of waist size has been used in some guidelines for defining the metabolic syndrome in children[32], we found that the associations between food intake and waist size using the 85th yielded very similar results and greater statistical power and so we present only that analysis. To allow for the comparison of the analysis results from the 1999–2002 surveys with those from NHANES III, we used the same age- and sex-specific cut points of WC (derived from the NHANES III distributions) to define children with (≥85th percentile) and without (<85th percentile) central obesity.

The potential confounders retained in the final models were those that led to meaningful changes in the adjusted mean dietary intakes, including age, race/ethnicity, height, number of hours of daily television viewing, Tanner stage of pubertal development and parental education or income level. For the approximately 1·5 % of subjects who had missing data on parental education, we used a dummy variable to substitute missing education information. Analyses were conducted including and excluding the dummy variable for education and the results were nearly identical, leading us to conclude that the inclusion of these subjects was unbiased.

Results

Descriptive characteristics for the 3761 children aged 5–11 years and the 1803 adolescents aged 12–16 years are shown in Table 1. On average, the 5- to 11-year-olds were slightly less than 8 years of age while the adolescents were about 14 years of age. Boys in both age groups consumed more dairy, vegetables, grains and meats/other non-dairy proteins than did girls. While there were no apparent gender-related differences in WC at these ages, girls did have higher levels of subcutaneous fat as assessed by the sum of subscapular and suprailiac skinfolds ($P < 0.05$ for all).

Tables 2 and 3 show adjusted mean food group intakes according to the age- and sex-specific quartiles of WC and sum of two skinfolds. At 5–11 years of age (Table 2) there were few differences in food intake associated with category of central body fat, although boys in the lowest quartile of WC or sum of two skinfolds consumed about half a serving less of meat/other protein than those in the highest quartile (e.g. 3·61 servings/d v. 4·14 servings/d for WC quartiles 1 and 4, respectively; P for trend = 0·025).

Among 12- to 16-year-old male and female adolescents (Table 3), intakes of dairy products and total grains were inversely associated with both measures of central body fat. For example, those in the lowest quartile of WC consumed nearly half a serving more of dairy per day than those in the highest quartile (P for trend = 0·001 and 0·015 for girls and boys, respectively). Similarly, those in the smallest WC quartile consumed more than one

Table 1 Characteristics of subjects by age and gender in the Third National Health and Nutrition Examination Survey

	Age 5–11 years				Age 12–16 years			
	Females (*n* 1895)		Males (*n* 1866)		Females (*n* 950)		Males (*n* 853)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (years)	7·7	2·1	7·8	2·1	14·0	1·4	13·9	1·4
Height (in)	50·9	5·9	51·1	5·4	62·9	2·9	65·0*	4·3
Height (cm)	129·3	15·0	129·8	13·7	159·8	7·4	165·1	10·9
Television (h/d)	2·2	1·5	2·3*	1·5	2·3	1·7	2·3	1·6
Total energy (kJ)	7313·1	2317·4	8326·7*	2679·6	8130·8	2996·5	10 372·4*	4133·2
Food group intake (servings/d)								
Dairy	1·9	1·2	2·2*	1·4	1·7	1·4	2·2*	1·8
Fruits	1·4	1·6	1·4	1·6	1·0	1·5	1·1	1·7
Vegetables	2·3	1·8	2·5*	2·1	2·8	2·4	3·2*	2·9
Grain	6·0	2·8	6·9*	3·4	6·3	3·4	8·5*	4·9
Meat/Non-dairy protein†	3·4	2·4	3·9*	2·8	4·0	3·0	5·4*	3·9
Waist circumference (cm)	60·0	10·1	60·4	10·3	75·4	12·0	75·6	13·3
Sum of two skinfolds (mm)‡	20·3	14·1	16·9*	13·1	33·3	16·6	24·6*	16·6
	n	%	*n*	%	*n*	%	*n*	%
Race/ethnicity								
Non-Hispanic whites	526	27·8	511	27·4	266	28·0	208	24·4
Non-Hispanic blacks	631	33·3	640	34·3	346	36·4	305	35·7
Mexican-American	738	38·9	715	38·3	338	35·6	340	39·9
Parental education‡								
Less than high school	785	42·1	731	39·9	385	40·9	363	42·8
High school	577	31·0	590	32·2	298	31·7	282	33·3
More than high school	501	26·9	510	27·9	258	27·4	203	23·9

*Mean value was significantly different from that of females (*P* < 0·05).
†Meat/Non-dairy protein = total ounce servings of meat, fish, poultry and other non-dairy sources of protein.
‡Data were missing for subscapular skinfold (*n* 37), suprailiac skinfold (*n* 54), both skinfolds (*n* 21) and parental education (*n* 81).

Table 2 Adjusted mean food intakes according to anthropometric measures of central obesity: children aged 5–11 years (Third National Health and Nutrition Examination Survey)

		Servings per day†									
		Dairy		Fruit		Vegetables		Grains		Meat/Protein	
Central obesity measures	*n*	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Girls											
Waist circumference (cm)											
Quartile 1	471	1·75	0·06	1·35	0·08	2·20	0·09	5·77	0·14	3·40	0·12
Quartile 2	475	1·99	0·06	1·45	0·07	2·25	0·09	6·02	0·13	3·35	0·11
Quartile 3	473	2·04	0·06	1·44	0·07	2·33	0·09	6·11	0·13	3·29	0·11
Quartile 4	476	1·85	0·06	1·37	0·08	2·38	0·09	5·91	0·14	3·45	0·12
P for trend		0·106		0·835		0·113		0·171		0·973	
Sum of two skinfolds (mm)											
Quartile 1	465	1·96	0·06	1·37	0·08	2·23	0·09	6·03	0·13	3·34	0·11
Quartile 2	471	1·95	0·06	1·41	0·07	2·21	0·09	6·05	0·13	3·37	0·11
Quartile 3	472	1·90	0·06	1·50	0·07	2·28	0·09	5·95	0·13	3·45	0·11
Quartile 4	467	1·83	0·06	1·30	0·08	2·43	0·09	5·77	0·14	3·30	0·11
P for trend		0·106		0·835		0·113		0·171		0·973	
Boys											
Waist circumference (cm)											
Quartile 1	466	2·16	0·07	1·32	0·08	2·50	0·11	6·93	0·17	3·61	0·14
Quartile 2	465	2·20	0·06	1·38	0·07	2·54	0·10	7·09	0·16	3·91	0·13
Quartile 3	470	2·17	0·06	1·33	0·07	2·53	0·10	6·82	0·15	3·84	0·13
Quartile 4	465	2·23	0·07	1·49	0·08	2·49	0·11	6·65	0·17	4·14	0·14
P for trend		0·560		0·248		0·937		0·176		0·025	
Sum of two skinfolds (mm)											
Quartile 1	457	2·13	0·07	1·41	0·08	2·62	0·10	6·96	0·16	3·56	0·13
Quartile 2	461	2·27	0·06	1·39	0·07	2·41	0·10	7·22	0·16	3·82	0·13
Quartile 3	463	2·15	0·06	1·33	0·07	2·56	0·10	6·67	0·15	3·98	0·13
Quartile 4	459	2·20	0·07	1·41	0·08	2·45	0·10	6·62	0·16	4·05	0·13
P for trend		0·774		0·805		0·498		0·033		0·008	

†Food group means are adjusted for exact age, height, race/ethnicity, hours per day watching television, Tanner stage and parental education.

Table 3 Adjusted mean food intakes according to anthropometric measures of central obesity: adolescents aged 12–16 years (Third National Health and Nutrition Examination Survey)

		Servings per day†									
		Dairy		Fruit		Vegetables		Grains		Meat/Protein	
Central obesity measures	n	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Girls											
Waist circumference (cm)											
Quartile 1	235	1·76	0·09	1·05	0·10	2·70	0·16	6·76	0·23	3·96	0·20
Quartile 2	239	1·86	0·09	1·10	0·10	3·03	0·15	6·53	0·22	4·13	0·19
Quartile 3	238	1·67	0·09	0·99	0·10	2·71	0·16	6·18	0·22	3·95	0·19
Quartile 4	238	1·34	0·09	1·04	0·10	2·66	0·16	5·64	0·22	3·94	0·20
P for trend		0·001		0·762		0·521		0·0003		0·773	
Sum of two skinfolds (mm)											
Quartile 1	224	1·86	0·10	0·96	0·10	2·73	0·16	6·83	0·23	3·99	0·20
Quartile 2	230	1·68	0·09	1·13	0·10	2·82	0·15	6·51	0·23	3·90	0·20
Quartile 3	231	1·72	0·09	1·03	0·10	2·91	0·15	6·14	0·23	4·06	0·20
Quartile 4	226	1·44	0·10	1·12	0·10	2·52	0·16	5·70	0·23	4·01	0·20
P for trend		0·006		0·443		0·446		0·0003		0·806	
Boys											
Waist circumference (cm)											
Quartile 1	213	2·48	0·13	1·33	0·13	3·33	0·21	8·87	0·35	4·87	0·28
Quartile 2	211	2·22	0·12	1·28	0·12	3·22	0·20	8·80	0·33	5·33	0·27
Quartile 3	215	2·02	0·12	0·99	0·12	3·39	0·20	8·61	0·33	5·72	0·27
Quartile 4	214	2·05	0·13	0·95	0·12	2·87	0·21	7·56	0·34	5·63	0·27
P for trend		0·015		0·016		0·016		0·011		0·047	
Sum of two skinfolds (mm)											
Quartile 1	207	2·37	0·13	1·30	0·12	3·42	0·21	9·35	0·35	4·88	0·28
Quartile 2	205	2·31	0·12	1·30	0·12	3·25	0·20	8·88	0·34	5·57	0·27
Quartile 3	208	2·14	0·12	1·08	0·12	3·31	0·20	8·15	0·34	5·45	0·27
Quartile 4	206	2·04	0·13	0·89	0·12	2·93	0·21	7·67	0·34	5·61	0·28
P for trend		0·047		0·012		0·141		0·0003		0·102	

†Food group means are adjusted for exact age, height, race-ethnicity, hours per day watching TV, Tanner stage, and parental education.

additional serving of grain per day than those in the highest quartile (P for trend = 0·0003 and 0·011 for girls and boys, respectively). Neither fruit nor vegetable intake was associated with central adiposity in girls. However, adolescent boys with the largest waist (and skinfold) measures consumed the least amount of fruit (P for trend = 0·016 and 0·012 for WC and skinfolds, respectively) and the fewest vegetables (P for trend = 0·016 for WC). Finally, there was also a tendency for adolescent boys in the lowest quartile of WC to consume less meat (P for trend = 0·047).

Table 4 examines the association between food intake and central obesity by classifying those with WC at or above the age- and sex-specific 85th percentile as having central obesity. We conducted the analyses in both NHANES III and NHANES 1999–2002. The analyses in Table 4 are restricted to adolescents. Identical analyses were carried out among 5- to 11-year-old children (not shown) but, as was found in Table 2, there were no meaningful or statistically significant differences in the major food group intakes associated with WC. In both surveys, adolescents with central obesity (WC ≥ 85th percentile) consumed less dairy and fewer grains and had lower intakes of total fruit and vegetables ($P = 0·0002$, $P < 0·0001$ and $P = 0·045$, respectively, in NHANES III; $P = 0·0009$, $P = 0·0002$ and $P = 0·062$, respectively, in

NHANES 1999–2002). While the majority of the dairy consumed was in the form of milk, both milk ($P = 0·004$) and cheese intakes ($P = 0·020$) were inversely associated with central obesity in NHANES III while only the association with milk consumption was significantly different ($P = 0·0008$) in the later NHANES sample; too few subjects consumed yoghurt to evaluate its effect separately. Central obesity was similarly related to whole and refined grain intakes ($P = 0·002$ and $P = 0·001$, respectively, in NHANES III; $P = 0·006$ and $P = 0·003$, respectively, in NHANES 1999–2002). There was no consistent association between central obesity and the intake of meat and meat equivalents. Finally, we compared the discretionary fat intakes of children with and without central obesity, and found that children without central obesity reported consuming more discretionary fat than children with central obesity ($P < 0·0001$ in NHANES III; $P = 0·003$ in NHANES 1999–2002).

Discussion

The present paper explores the relationship between food group intake and central obesity among children and adolescents. The results suggest that intakes of dairy and grains as well as the combined intakes of fruit and

Table 4 Association between food intake and waist size in adolescents in NHANES III and NHANES 1999–2002

Total food groups and subgroups	Servings per day† NHANES III WC < 85th percentile§ (n 1517) Mean	SE	WC ≥ 85th percentile§ (n 286) Mean	SE	P value	Servings per day‡ NHANES 1999–2002 WC < 85th percentile§ (n 1509) Mean	SE	WC < 85th percentile§ (n 284) Mean	SE	P value
Dairy (total)	1·97	0·04	1·58	0·10	0·0002	1·92	0·04	1·68	0·06	0·0009
Milk	1·32	0·03	1·06	0·08	0·004	1·27	0·03	1·05	0·06	0·0008
Cheese	0·64	0·02	0·51	0·05	0·020	0·64	0·02	0·61	0·03	0·505
Fruit and vegetables (total)	4·13	0·08	3·72	0·19	0·045	4·07	0·07	3·79	0·13	0·062
Fruit (total)	1·11	0·04	0·98	0·10	0·234	1·37	0·04	1·14	0·08	0·012
Citrus, melon, berries	0·61	0·03	0·46	0·07	0·062	0·68	0·03	0·63	0·06	0·401
Other fruit	0·50	0·03	0·52	0·06	0·775	0·68	0·03	0·51	0·05	0·003
Vegetables (total)	3·02	0·07	2·74	0·16	0·102	2·71	0·06	2·65	0·10	0·640
Dark green	0·08	0·01	0·05	0·03	0·307	0·06	0·01	0·09	0·01	0·102
Deep yellow/orange	0·08	0·01	0·08	0·02	0·964	0·09	0·01	0·07	0·01	0·188
Potatoes (white) & other starchy	1·66	0·05	1·49	0·12	0·207	1·47	0·04	1·43	0·08	0·673
Other vegetables (including tomatoes)	1·21	0·03	1·12	0·08	0·333	1·09	0·03	1·07	0·05	0·701
Grains (total)	7·50	0·11	6·30	0·25	<0·0001	7·30	0·09	6·61	0·16	0·0002
Refined grains	6·58	0·10	5·70	0·24	0·001	6·51	0·09	5·99	0·15	0·003
Whole grains	0·92	0·04	0·60	0·09	0·002	0·79	0·03	0·62	0·05	0·006
Meat and other protein (total)	4·65	0·09	4·69	0·21	0·856	4·30	0·08	4·24	0·13	0·730
Red meat (beef, pork, lamb)	1·97	0·07	1·90	0·15	0·651	1·68	0·06	1·77	0·10	0·404
Processed (franks, sausage, luncheon meats)	0·76	0·04	0·72	0·09	0·692	0·74	0·03	0·79	0·06	0·450
Poultry, fish, shellfish	1·41	0·07	1·57	0·16	0·359	1·46	0·05	1·19	0·09	0·013
Eggs, nuts, seeds, soya	0·50	0·02	0·50	0·06	0·975	0·42	0·02	0·48	0·04	0·106
Nuts and seeds	0·17	0·02	0·14	0·04	0·479	0·11	0·01	0·11	0·01	0·662
Discretionary fat (g)	66·98	0·87	55·52	2·03	<0·0001	63·63	0·76	59·04	1·32	0·003

NHANES, National Health and Nutrition Examination Survey; WC, waist circumference.
†Adjusted for exact age, gender, height, race/ethnicity, hours per day watching television, Tanner stage and parental education.
‡Adjusted for exact age, gender, height, race/ethnicity, hours per day watching television and parental income.
§Age- and gender-specific cut-off points of WC from the NHANES III data set were used.

vegetables are associated with lower levels of central body fat, particularly among adolescents.

The literature related to dietary intake and central obesity in children is very limited. These results are consistent with a report from the National Growth and Health Study which found that adolescent white females following a 'healthy dietary pattern' (i.e. higher intakes of dairy, fruits, vegetables and grains) had smaller increases in WC over 10 years[33]. A larger number of studies have examined the relationship of food group intake and overall adiposity among children. Regarding dairy, for instance, some data indicate that higher dairy intakes are associated with significantly lower body fat levels through childhood[34–36], although a review of the evidence in 2005 concluded that there was insufficient evidence at that time to draw firm conclusions regarding the effect of Ca or dairy intake on body fat[37].

While higher fruit and vegetable consumption is thought to be associated with a healthy body weight in children, a recent review concluded that more evidence is needed to support this conclusion[38] and it has been suggested that the methods of preparation (e.g. frying) and serving (e.g.

with sauce) may account for the apparent inconsistent protective effect. Data on the relationship of grains and weight in children are limited. One prospective study demonstrated smaller annual weight change in relation to each additional serving of breads/grains[39] and another[40] found that cereal consumption was related to lower BMI; neither of these studies distinguished between refined and whole grains. In the current cross-sectional study, we saw that adolescents whose waist circumference was above the 85th percentile reported consuming less discretionary fat than those with less central body fat. There are several possible explanations for this finding. First, reporting bias is a possibility, with more under-reporting of added fat among children with more central adiposity. It could be, however, that more overweight adolescents are in fact consuming less added fat. For example, in our own observations (ML Singer and LL Moore, unpublished results), we found that overweight children and adolescents more often consumed low-fat dairy products than those who are of normal weight. Finally, we note that discretionary fat does not necessarily reflect the total fat load of

the diet. The correlations between discretionary fat and percentage of energy from total fat were 0·56 and 0·58 in NHANES III and NHANES 1999–2002 samples, respectively.

Several studies have examined food group intake and central obesity among adults. One such cross-sectional study of middle-aged adults found an inverse relationship between a dietary pattern characterized by frequent intake of raw and salad vegetables and seasonal fruits (and low intakes of fried foods including potatoes) and central obesity[18]. One prospective study found that a pattern characterized by high intakes of fruit, vegetables, reduced-fat dairy and whole grains and low intakes of red and processed meat was associated with smaller gains in central obesity[18], while another found an inverse association between a dietary pattern of high fruits and vegetables and low-fat dairy and WC among women[41]. The CARDIA study identified an inverse association between higher dairy intake and lower waist:hip ratio among young adults[42] and at least one small trial found dairy to be inversely related to central fat loss among obese subjects[43]. Similar results have been found for whole grain consumption and cereal fibre[44,45]. In terms of meat intake, high intakes of both red and processed meat have been shown to be positively related to the likelihood of central weight gain over a 10-year period in several studies[46,47].

A number of possible explanations exist for the findings of these studies. Dairy foods have been hypothesized to be associated with lower levels of body fat through the effects of their Ca content on lipogenesis[48]. Dairy is also an important source of protein and protein-rich diets have been shown to promote satiety[49]. The dairy protein, whey, is also a rich source of the essential amino acid leucine that is involved in the partitioning of dietary energy[50]. The effects of whole grains on obesity are believed to relate to their soluble fibre content, which is associated with increased satiety, delayed gastric emptying and enhanced insulin sensitivity[51,52]. Fruits and vegetables are also important sources of fibre and may have similar effects on satiety and satiation[53].

The limitations of our exploratory study must be acknowledged. As with any self-reported dietary record, there is the real possibility of misrepresentation of dietary intake. Subjects for whom weight or body proportions are of concern may certainly tend to understate aspects of their intake. The cross-sectional design of NHANES also prevents any conclusions related to cause and effect.

The availability of a single day's dietary recall limits the precision of the estimated dietary intakes of individuals. However, a single 24 h dietary recall provides accurate estimates of mean dietary intake within groups[54]. Thus, the recalls used in NHANES are appropriate for quantifying mean food intakes associated with quartiles of central body fat.

The NHANES data set offers important strengths as well. The large, randomly selected group of children and adolescents provides sufficient power to explore a broad range of intake levels in different food groups. The availability of data from each of the USDA Food Pyramid groups, including information from single food sources and mixed dishes, is a strength of the study. Most studies of food effects on health outcomes have relied on intakes from FFQ, which yield less precise estimates of food servings from all sources. For example, it is not possible to extract the actual number of grain servings from all sources in an FFQ since many of the servings would be derived from composite foods such as pizza or lasagne.

In summary, the current cross-sectional study demonstrates an association between the patterns of food intake during adolescence and the prevalence of excess central body fat. The intakes of dairy and grains, especially whole grains, as well as total fruits and vegetables were inversely associated with central obesity among these adolescents. These associations were not fully explained by total body fat as measured by BMI.

The USDA provides food-based dietary guidelines that are specific to age, sex and physical activity level. Prospective studies are needed to test the effects of these recommendations on the development of central obesity in children and adolescents. The present study is an important first step towards such future work.

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