

Diet composition, energy intake, and exercise in relation to body fat in men and women¹⁻³

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ABSTRACT This study examined the relationships among body fat, diet composition, energy intake, and exercise in adults. Male ($n = 107$) and female ($n = 109$) adults aged 18–71 y (36.6 ± 1.0 y, $\bar{x} \pm \text{SEM}$) were hydrostatically weighed to determine body fat (5.7–49.0% of total weight). Diet and exercise behaviors were determined by use of a questionnaire. As body fat increased, percent of energy intake derived from fat increased ($p < 0.001$) whereas the percent from carbohydrate decreased ($p < 0.001$). There was no relationship between energy intake and adiposity although leanness and exercise were related ($p < 0.001$). When subgroups of lean and obese subjects were compared, the lean subjects derived ~29% of their energy from fat and 53% from carbohydrate vs 35% and 46%, respectively, for the obese subjects. No differences were found between groups for energy intake but the lean individuals exercised more often than did the obese individuals. These data suggest that diet composition may play as important a role in fat deposition as do energy intake and lack of exercise. *Am J Clin Nutr* 1990;52:426–30.

KEY WORDS Obesity, body composition, energy intake, diet composition, dietary fat, dietary carbohydrate, exercise

Introduction

Heredity, diet, and energy expenditure are the three factors usually considered to control fat deposition in the development of obesity. Although diet and energy expenditure are considered direct inducers of obesity, heredity is indirect; it regulates an individual's response to diet and/or activity. Regardless of the obesity-promoting factor, the underlying assumption in fat deposition is the principle of energy balance: if individuals consume more energy than they expend, weight gain follows, and if individuals expend more energy than they consume, weight loss follows. If this principle is valid then the only explanation for obesity is hyperphagia and/or hypoactivity.

However, this principle of energy balance may be more complicated than originally assumed. For example, studies have shown that dietary fat and sugar can promote obesity without excessive energy intake (1–4). This implies that diet composition may be as important as energy content in promoting obe-

sity. Supporting this view is the theory that obese individuals prefer fat-rich, sugar-rich, or fat-rich plus sugar-rich foods (5–14). Although it is still unknown whether consumption of these foods causes hyperphagia, there is a body of evidence suggesting that obese individuals do not consume more joules than do their nonobese counterparts (8, 13–18).

Several studies have attempted to determine the relationships among adiposity, diet composition, energy intake, food preferences, and eating behavior (5–20). A problem with these studies is weak methodology. For example, all but two of the studies used hedonic-response ratings or some equivalent scale rating system that subjectively evaluate food preferences or eating behavior. Indirect or subjective methods such as regression equations, circumference measurements, body somatotypes, and body mass indices were also used to estimate body fat. Only one study (14) analyzed both diet and body composition directly; however, only middle-aged men were studied. Therefore, the purpose of this study was to evaluate the relationships among body fat, diet composition, energy intake, and exercise patterns in adult males and females by use of direct methods of body composition measurement and diet analysis.

Subjects and methods

Subjects

Subjects for this study were adult males ($n = 107$) and females ($n = 109$) from central Indiana who responded to advertisements for volunteers sent from the Indiana University Weight Loss Clinic. The majority of subjects were faculty, staff, and students from the university community. The ethnic background of 94% of the sample population was white (European descent); 6% were either black, Asian, or Indian. Approximately 8% of the participants were involved in a structured fitness program. Each subject signed an informed consent form, previously approved by the Indiana University Committee for

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TABLE 1
Subject characteristics*

	Age	Weight	Percent body fat	Lean body mass
	y	kg	%	kg
Males (n = 107)	39.6 ± 1.2 (18–71)	84 ± 2 (60–157)	21.2 ± 0.8 (5.7–40.1)	65 ± 1 (50–99)
Females (n = 109)	33.6 ± 0.9 (18–64)	69 ± 2 (44–126)	30.0 ± 0.9 (10.0–49.0)	47 ± 1 (36–83)

* $\bar{x} \pm \text{SEM}$; range in parentheses.

the Protection of Human Subjects, which described all test procedures and possible risks. The characteristics of the participants are listed in **Table 1**.

Methods

Each subject reported to the laboratory after an overnight fast and was hydrostatically weighed at residual volume according to the methods of Wilmore (21). Percent body fat was calculated by use of the Siri equation (22). Subjects were then given an eating- and exercise-behavior questionnaire. This questionnaire consists of four parts that evaluate the antecedents to eating, eating behavior, exercise behavior, and consequences of eating (23). Questions in the antecedent section evaluate eating responses to certain cues such as television viewing, food advertisements, or emotions. The eating-behavior section evaluates how often a person eats as well as how fast he or she eats. The exercise part of the questionnaire determines the frequency of exercise in addition to the structure of the exercise program. Questions in the consequences portion of the evaluation determine whether reinforcement or rewards are part of one's eating and exercise behavior. The questions relative to frequency of eating and exercise behavior are quantitative whereas all other questions are qualitative. This eating- and exercise-behavior questionnaire was found to have concurrent validity as well as a test-retest reliability of 0.95 (24).

Next, a dietitian, using plastic-food replicas, instructed the subjects on how to estimate food portions so as to be as accurate as possible in measuring food consumption. Dietary recall was then performed for the 24 h before testing. A 2-d food diary was then used to record all food and beverage intake over one additional weekday and 1 weekend day. Also employed to measure food and beverage consumption was the *Right Byte* (N-Squared Computing, Silverton, OR), an extended diet history that records specific food frequency intake over periods of up to 1 mo. Data from the food diary and *Right Byte* were averaged together and the *Nutritionist III* nutrient data bank (N-Squared Computing) was used for diet analysis.

After data analysis of each group as a whole, the group was subsequently divided into a lean and obese subgroup by gender. For males lean was defined as $\leq 15\%$ body fat and obesity was defined as $\geq 25\%$ body fat, for females the values were $\leq 20\%$ and $\geq 35\%$ body fat, respectively.

Statistical analysis

The strength of relationships among diet, body composition, and behavior were measured by the coefficient of linear correlation. The intent of this correlative analysis was to determine if the relationship between two variables was different from zero;

hence, a one-tailed test was employed. Significance was accepted at $p < 0.01$. Comparisons among mean values for the lean and obese subgroups were performed by the use of a one-way analysis of variance. Significance at $p < 0.05$ warranted the use of the Newman-Keuls post hoc test (25).

Results

Correlative analysis revealed that body weight was positively correlated with percent body fat for both males ($r = 0.70$) and females ($r = 0.81$). Body weight was also positively correlated with lean body mass. However, this relationship was weaker for males ($r = 0.23$, $p < 0.01$) than for females ($r = 0.41$, $p < 0.001$). The difference was most likely due to muscular hypertrophy, which contributed to body weight to a greater extent in males than in females.

The relationships among adiposity and dietary nutrients or energy intake are shown in **Table 2**. Adiposity was positively related to dietary fat content and inversely related to dietary carbohydrate consumption for both genders. This suggests that as the ratio of fat- to carbohydrate-derived energy in the diet was increased, fat deposition increased. High adiposity was also characterized by decreased sugar intake and increased total energy consumption for women but not for men. However, when energy intake was expressed per kilogram lean body mass, there was no relationship between adiposity and energy consumption. In addition, fatter individuals ate fewer joules per kilogram body weight than did leaner individuals. This further demonstrated the absence of a relationship between body fat and hyperphagia.

TABLE 2
Cross-sectional correlation coefficients of percent body fat vs nutrients or daily energy intake

	Males	Females
Nutrient (% of daily energy intake)		
Protein	0.01	0.12
Fat	0.38*	0.37*
Carbohydrate	-0.30*	-0.39*
Sugar	0.14	-0.36*
Alcohol	0.00	0.00
Daily energy intake		
Total (kJ)	0.08	0.32*
By body weight (kJ/kg body wt)	-0.42*	-0.37*
By lean body mass (kJ/kg LBM)	0.15	0.14

* $p < 0.001$. LBM, lean body mass.

TABLE 3

Cross-sectional correlation coefficients of age vs nutrients or body composition

	Males	Females
Nutrient (% of daily energy intake)		
Fat	0.07	0.22*
Carbohydrate	0.10	-0.31†
Sugar	0.07	-0.24*
Body composition		
Body weight	0.00	0.38†
Percent body fat	0.34†	0.41†

* $p < 0.01$.† $p < 0.001$.

Additional information relative to the development of obesity can be seen in Table 3. Age was correlated with increased fat deposition in males but not to body weight or any dietary variable. Older females on the other hand seemed to be heavier as well as fatter, consume more fat, and eat less carbohydrate and sugar than did younger females. No other variables correlated significantly with age for either group.

Group analysis for comparing the lean and obese subjects of each sex is presented in Table 4. The most significant findings were that the obese subjects derived a greater percentage of their energy from fat and less from carbohydrate than did the lean subjects; and that energy intake expressed as total joules or joules per lean body mass were similar between the obese and lean subjects. Because of this equivalence in total energy intake, the obese subjects ate less joules per kilogram body weight than did the lean subjects. The obese women consumed less sugar than did the lean women, which was previously reflected in the correlational analysis for the whole group (Table 2). Note that diets of obese females were the same as diets of

obese males, and that diets of lean females were the same as diets of lean males. This held true for all nutrients as well as energy intake, except when lean males consumed more energy than did lean females.

Evaluation of the eating- and exercise-behavior questionnaire revealed some specific behavior patterns with respect to body fat. Correlation data revealed that obese males ($r = -0.44$, $p < 0.001$) and females ($r = -0.39$, $p < 0.001$) scored lower in exercise behavior than did their leaner counterparts. Obese subjects from each sex also scored lower with respect to responses to eating cues (males, $r = -0.26$, $p < 0.005$; females, $r = -0.36$, $p < 0.001$). Lower scores in eating behavior for males ($r = -0.28$, $p < 0.001$) were correlated with elevated adiposity whereas there was no such correlation for females. Total scores on the eating- and exercise-behavior questionnaire were significantly ($p < 0.001$) related to body fat (males, $r = -0.47$; females, $r = -0.38$).

Group comparisons revealed no significant differences in eating and exercise behaviors between lean men and lean women or between obese men and obese women (Table 5). However, both lean men and lean women scored higher on the questionnaire than did their obese counterparts. According to the higher scores in the antecedent scoring section, lean individuals responded better to eating cues than did obese individuals. The lean subjects also scored higher in the exercise section of the questionnaire. When just frequency of exercise scores was compared among groups, lean subjects exercised more often than did the obese. Lean men and women exercised on average 5–6 d/wk compared with 1–2 d/wk for obese subjects ($p < 0.01$, data not shown).

Discussion

The most significant finding from this study is that diet content rather than energy consumption was characteristic of in-

TABLE 4

Comparisons among anthropometric and dietary variables of obese and lean adults*

	Lean males ($n = 27$)	Obese males ($n = 35$)	Lean females ($n = 19$)	Obese females ($n = 26$)
Variable				
Age (y)	32.8 ± 1.8	44.3 ± 2.2†	28.9 ± 1.2	39.0 ± 2.0‡
Body weight (kg)	72.7 ± 1.4	97.4 ± 3.4†	52.6 ± 1.2†	90.0 ± 3.1‡
Percent body fat (%)	11.2 ± 0.6	30.2 ± 0.7†	16.7 ± 0.7†	42.8 ± 0.7‡§
LBM (kg)	63.8 ± 1.3	67.3 ± 1.8	43.8 ± 1.1†	51.1 ± 1.6‡§
Nutrients (% of daily energy intake)				
Protein	17.0 ± 0.6	16.7 ± 0.4	16.4 ± 0.8	16.8 ± 0.8
Carbohydrate	52.6 ± 1.3	48.0 ± 1.1†	52.9 ± 1.5	44.3 ± 1.7‡
Fat	28.7 ± 1.0	33.1 ± 1.0†	28.6 ± 1.5	36.3 ± 1.5‡
Sugar	20.0 ± 1.1	17.9 ± 1.1	20.7 ± 0.8	15.1 ± 1.2‡
Alcohol	1.9 ± 0.5	2.3 ± 0.5	2.1 ± 0.5	2.2 ± 0.7
Daily energy intake				
Total (kJ)	12.1 ± 0.6	11.2 ± 0.7	8.6 ± 0.6†	10.6 ± 0.9
By body weight (kJ/kg body wt)	35.2 ± 2.1	24.7 ± 1.7†	33.5 ± 2.1	24.3 ± 1.7‡
By lean body mass (kJ/kg LBM)	39.8 ± 2.5	35.2 ± 2.1	40.6 ± 2.5	42.7 ± 2.9

* $\bar{x} \pm \text{SEM}$.† Significantly different from lean males, $p < 0.05$.‡ Significantly different from lean females, $p < 0.05$.§ Significantly different from obese males, $p < 0.05$.

TABLE 5
Comparisons among eating- and exercise-behavior questionnaire scores of obese and lean adults*

	Lean males	Obese males	Lean females	Obese females
Total score	27.9 ± 0.8	21.7 ± 1.3†	28.7 ± 1.5	20.5 ± 1.3‡
Exercise scores	5.8 ± 0.4	3.1 ± 0.4†	6.0 ± 0.7	2.6 ± 0.5‡
Antecedent scores	7.9 ± 0.4	6.3 ± 0.5†	7.4 ± 0.5	5.0 ± 0.4‡
Eating-behavior scores	13.2 ± 0.2	11.4 ± 0.6	13.8 ± 1.0	12.2 ± 0.7
Consequence scores	0.7 ± 0.2	1.0 ± 0.3	0.9 ± 0.3	0.8 ± 0.2

* $\bar{x} \pm \text{SEM}$.

† Significantly different from lean males, $p < 0.01$.

‡ Significantly different from lean females, $p < 0.01$.

creased adiposity for both male and female adults. This was demonstrated by correlation data through a wide range of adiposity and age (Table 2), as well as by group comparisons between lean and obese adults (Table 4). The fact that fatter individuals derive a greater portion of their energy from fat was suggested previously (5–14) and demonstrated in middle-aged males (14). The generally accepted explanation for dietary fat-induced obesity is hyperphagia caused by the caloric density of fat being greater than that of carbohydrate or protein. However, results from this study show that adiposity was not related to either absolute or relative energy intake for males and only to absolute energy intake for females; this relationship disappeared when consumption was expressed relative to body weight or lean body mass. Dreon et al (14) similarly found no relationship between energy intake and body fat in middle-aged men. Studies in the German Democratic Republic (8) and from the National Health and Nutrition Examination Survey (15) that used large databases, indicate that normal-weight and overweight persons ingest about the same number of joules.

The contribution of carbohydrate to the daily energy value of obese adults was less than that for the lean adults. Fatter women also ate less sugar than did lean women. These results are in contrast to the hypothesis that obese individuals prefer highly sugared foods (5–7, 10–11) but agree with evidence from Drewnowski et al (12) that suggests that obese individuals prefer a higher lipid content and lower sucrose content in their food than do normal-weight individuals. Ries (8) showed that overweight individuals consume less sugar and more high-fat foods than do normal-weight individuals. On the other hand, Grinker (19) and Grinker et al (20) found no differences in sensitivity or preference to sweet taste between obese and non-obese individuals. When we subsequently analyzed the diets of both genders for intakes of sucrose, fructose, maltose, glucose, lactose, and galactose separately, we found no relationship between the intake of any one sugar and adiposity. Although beyond the scope of this project, it is possible that obese individuals consumed more added sugars and less natural sugars than did lean individuals, even though their total carbohydrate consumption was lower.

It is particularly interesting that group analysis across sexes revealed only one significant difference between lean-to-lean or obese-to-obese comparisons: lean males consumed more joules than did lean females (Table 4). This can probably be explained

by the large difference in lean body mass between the two groups. Therefore, in this study, the only distinct difference in eating behavior between lean and obese adults of either sex was the relative proportion of energy intake derived from fat and carbohydrate. This does not eliminate hyperphagia as an inducer of obesity but suggests that diet composition may play just as important a role as does energy content of the diet in the development of obesity.

Data from the eating- and exercise-behavior questionnaire indicate that leanness was associated with healthier behavior, particularly in the area of exercise. At a glance this suggests that hypoactivity contributes to the development of obesity. However, from these data we cannot determine whether hypoactivity increased adiposity or whether adiposity decreased exercise activity. Whichever the case, healthier eating behavior along with increased exercise were characteristic of the lean state.

These data suggest that body fat is related to diet composition and exercise activity rather than to energy intake; and if hyperphagia promotes adiposity, then hyperphagia must be relative to activity level or metabolic rate and not to any anthropometric measurement. 

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