Occasional physical inactivity combined with a high-fat diet may be important in the development and maintenance of obesity in human subjects[1–3]

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ABSTRACT

Background: A better understanding of the environmental factors that contribute to obesity is imperative if any therapeutic effect on the increasing prevalence of overweight and obesity in the United States is to be achieved.

Objective: This study examined the effect of the interaction of diet composition and physical inactivity on energy and fat balances.

Design: Thirty-five normal-weight and obese subjects were randomly assigned to either a 15-d isoenergetic high-carbohydrate (HC) or high-fat (HF) diet according to a crossover design. During the first 14 d, body weight and physical activity were maintained. On day 15, subjects spent 23 h in a whole-room indirect calorimeter and were fed a diet similar to that consumed during the previous 7 d while remaining physically inactive.

Results: Energy intakes required to maintain body weight stability during the first 14 d were similar between diets. Normal-weight and obese subjects consuming both diets had a positive energy balance on the sedentary day (day 15), suggesting that subjects were less active in the calorimeter. There was no significant effect of diet composition on total energy balance and total protein-energy balance on day 15; however, carbohydrate balance was more positive with the HC (2497.8 ± 301.2 kJ) than with the HF (1159 ± 301.2 kJ) diet ($P = 0.0032$). Most importantly, fat balance was more positive with the HF (1790.8 ± 510.4 kJ) than with the HC (−62.8 ± 510.4 kJ) diet ($P = 0.0011$).

Conclusion: Chronic consumption of a high-carbohydrate diet could provide some protection against body fat accumulation in persons with a pattern of physical activity that includes frequent sedentary days. *Am J Clin Nutr* 2001;73:703–8.

KEY WORDS Obesity, energy metabolism, energy balance, fat balance, weight regulation, physical inactivity, high-fat diet

INTRODUCTION

On the basis of guidelines adapted recently for body weight and health (1), overweight [body mass index (BMI; in kg/m^2): 25–30] and obesity (BMI > 30) are now more common in the United States than is normal body weight (BMI < 25). The incidence of obesity increased dramatically over the past several decades (1). This increase has substantial health and economic implications that promise to burden the United States and many other developed and developing countries (1, 2).

Although there have been advances in the human genetics of obesity, researchers cannot blame genetics for the dramatic 20% increase in obesity that has occurred over the past decade (1). Therefore, other factors, such as physical inactivity and excessive energy intake (EI), are clearly contributory, indicating an urgent need to clarify and modify these factors. Many studies have reported the effects of diets high in fat with those low in fat on EI, energy expenditure (EE), and energy and nutrient balances (1, 3–6). In general, results suggest that obesity is more likely to occur in persons who eat a diet chronically high in fat than in those who eat a diet chronically low in fat (3, 7–11), perhaps because of the increased likelihood of overeating by those who consume diets high in fat (3, 5, 7, 12). However, several of these studies were conducted in subjects who maintained a constant physical activity level, a situation not likely to occur over time in many people. The purpose of this study was to examine the way in which habitual diet composition affected energy and fat balance on a day in which individuals were sedentary. Although the effects of high-fat diets and physical inactivity have been studied separately, the effects of both combined have rarely been studied, yet we believe that many US adults consume high-fat diets and are physically inactive.

SUBJECTS AND METHODS

Subjects

After the protocol was approved by the Colorado Multiple Institutional Review Board and the Scientific Advisory Committee

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of the General Clinical Research Center (GCRC) at the University of Colorado Health Sciences Center (UCHSC), 22 normal-weight subjects (8 women, 14 men) and 14 obese subjects (8 women, 6 men) gave their informed consent and were enrolled in the study. The subjects were between 25 and 34 y of age ($\bar{x}$ ± SEM: 29 ± 1 y), were at their maximum BMI (normal weight: 21.7 ± 0.5; obese: 33.1 ± 1.9), and had been weight-stable for ≥3 mo before enrollment. Each potential subject was given The Diet Habit Survey (13) to determine an estimate of the free-living diet composition at the time of screening.

Results of the screening laboratory tests were within normal limits for each individual and included urinalysis, complete blood counts, determination of liver and renal function, and measurements of serum electrolytes, fasting glucose, and thyroid-stimulating hormone. Fasting lipid concentrations, including triacylglycerol, cholesterol, HDL cholesterol, and LDL cholesterol were also within normal ranges. None of the subjects were taking medications that would affect lipid or carbohydrate metabolism.

Procedures

Each subject was admitted to the GCRC at the UCHSC on day 0 of the study protocol, at which time a fasting blood sample was drawn for measurements of serum glucose and insulin concentrations. At breakfast on day 0, the subjects began either a high-carbohydrate (HC) or high-fat (HF) mixed-food diet. Subjects were randomly assigned to either the HC or the HF diet on their first visit (day 0). Initial estimates were made of individual daily energy requirements for maintenance of admission weight, but the actual energy consumed was adjusted daily over the first 7 d to achieve weight stability. Individual daily EI remained unchanged over the last 7 d of each feeding period. The first diet (phase 1) was administered for 14 d, followed by a 23-h sedentary stay in a whole-room indirect calorimetry chamber on day 14. The subjects then were discharged for a 4–6-wk washout phase under free-living conditions, during which time they returned to the outpatient clinic once a week for weight measurement to determine weight stability. The washout phase was followed immediately by admission to the GCRC to begin the alternate experimental diet. The second diet (phase 2) also lasted 14 d and was followed by another 23-h sedentary stay in the whole-room indirect calorimetry chamber on day 14. Each diet was provided as 3 meals/d plus snacks by the metabolic kitchen of the GCRC. Breakfast had to be eaten every morning at the GCRC after measurement of body weight. The other 2 daily meals and snacks were prepared and packed up by the kitchen personnel and eaten by the subjects at a time of their choosing. Subjects were instructed to not consume any additional foods or drinks and to bring back to the GCRC any foods not consumed. Scheduling was designed to optimize the chances of studying each woman in the same phase of the menstrual cycle.

The HC diet provided 55% of energy as carbohydrate, 25% as fat, and 20% as protein; the HF diet provided 30% of energy as carbohydrate, 50% as fat, and 20% as protein. Daily EI was determined for each subject in kilocalories and converted to kilojoules by multiplying by 4.184. To maintain the admission weight, daily EI was controlled for by using approximate basal EE and self-reported physical activity levels. Subjects were encouraged to maintain their usual physical activity levels during the 14-d diet periods. Body weight was monitored daily and EIs were changed as necessary to maintain weight stability over the duration of each diet period. Body weight on day 0 of phase 1 was used as the goal weight for both diet phases. Diets were nutritionally adequate and matched for the ratio of polyunsaturated to saturated fat (≈0.3:1.0), total fiber content (14–18 g), and total cholesterol content (≈0.36 mg/kJ). An alcohol intake of 40 g/wk was factored into the energy prescription.

Whole-room indirect calorimetry chamber

At 0800 on the morning of day 14 of each diet phase, and after a 12-h overnight fast, subjects entered the whole-room indirect calorimetry chamber at the GCRC for an uninterrupted 23-h period. Subjects were provided no planned activities during the calorimetry stay and were essentially sedentary; they were allowed to read, write letters, and watch television. The experimental diet (HC or HF) consumed in the calorimeter provided the same daily isoenergetic content as consumed during the preceding 7 d. All urine output was collected over the 23-h period for measurement of urinary nitrogen. All subjects exited the chamber at 0700 on day 15.

The whole-room indirect calorimetry chamber at the GCRC is a small room (2.6 × 3.4 m) that contains a desk, a toilet, a telephone, a futon couch that unfolds into a bed, and a television with a video cassette recorder; the room is connected by phone to the nurses' station. An air lock allows food and other articles to be passed to the subjects while they are inside the chamber without disruption to the internal environment of the chamber.

The chamber functions as an open-circuit indirect calorimeter in which fresh air is drawn through the room by use of a computer-controlled blower system (Ametek Electromechanical Group, Kent, OH). The precise volume of air exchange is measured with a flow transducer with laminar flow element (Teledyne Brown Engineering, Hampton, VA). The difference in oxygen and carbon dioxide concentrations between air entering the chamber and air exiting the chamber was measured by using Hartman and Braun (Frankfurt, Germany) oxygen (Magnos 4 G) and carbon dioxide (Uras 3 G) analyzers. Calibration gases were made by mixing fresh air with nitrogen (with the oxygen analyzer) or carbon dioxide (with the carbon dioxide analyzer) with a Digimax mixing pump (Wosthoff OHG, Bochum, Germany). Oxygen consumption ($\dot{V}O_2$) and carbon dioxide production ($\dot{V}CO_2$) were determined from the flow rate and the differences in gas concentrations between entering and exiting air. Values were corrected for barometric pressure, ambient temperature, and humidity. EE was calculated from $\dot{V}O_2$ and nonprotein respiratory quotients (RQ = $\dot{V}CO_2$ produced/$\dot{V}O_2$ consumed) (14). The operation of the chamber was controlled by personal computer by using a software program written in MS Visual C/C++ (Microsoft, Redmond, WA). The program was based on calculations originally described by Jequier et al (14). Values for all indexes were averaged over 1-min intervals and recorded in 1-min intervals in a raw (ASCII) data file. Computed values for each variable were subsequently determined and recorded at 30-min intervals only. Data from the 23-h chamber stay were then extrapolated to a complete 24-h period. The accuracy and precision of this whole-room indirect calorimeter design was established previously by Hill et al (15).

Data collected during the chamber stay for both diets included 24-h RQ, 24-h EI, and 24-h EE. Energy balance for the 24-h period was calculated as the arithmetic difference between 24-h EI and 24-h EE. For each macronutrient substrate (carbohydrate, fat, and protein), 24-h determinations of intake and expenditure were made in grams and converted to kcal (carbohydrate

TABLE 1
Baseline characteristics of subjects[1]

	Normal weight		Obese	
	Women (n = 8)	Men (n = 13)	Women (n = 8)	Men (n = 6)
Age (y)[2]	27.9 ± 1.3	28.7 ± 0.7	31.8 ± 1.1	31.7 ± 1.4
Weight (kg)[2]	57.4 ± 2.0	75.5 ± 2.5	99.1 ± 9.9	99.1 ± 6.4
BMI (kg/m^2)[3]	20.2 ± 0.5	22.6 ± 0.6	35.9 ± 3.0	29.4 ± 1.0
RMR (kJ/d)[2,4]	5586 ± 255	7740 ± 209	8075 ± 824	8832 ± 322
RQ, fasting	0.81 ± 0.02	0.82 ± 0.02	0.78 ± 0.02	0.79 ± 0.02
Glucose (mmol/L)	4.7 ± 0.2	4.9 ± 0.1	5.0 ± 0.2	5.1 ± 0.2
Insulin (pmol/L)[2]	35.9 ± 5.0	40.9 ± 3.6	109.8 ± 23.7	111.2 ± 43.8

[1] Least-squares means ± SEMs. RMR, resting metabolic rate; RQ, respiratory quotient (carbon dioxide production/oxygen consumption). To convert RMR in kJ to kcal, divide by 4.184; to convert glucose in mmol/L to mg/dL, divide by 0.05551; to convert insulin in pmol/L to U/mL, divide by 7.175.

[2] Significant difference between normal-weight and obese subjects (adjusted for sex), $P < 0.05$.

[3] Significant interaction (significantly different group effect for men and women), $P < 0.05$.

[4] Significant difference between men and women (adjusted for group), $P < 0.05$.

× 4 kcal/g, fat × 9 kcal/g, and protein × 4 kcal/g). Carbohydrate and fat expenditure were determined from total EE and the nonprotein RQ (14), and protein expenditure was determined from 24-h urinary nitrogen excretion (16). For each substrate, 24-h balance was calculated as the difference between 24-h intake and 24-h expenditure.

Laboratory procedures

Serum insulin concentrations were measured by radioimmunoassay (17). Total urinary nitrogen was measured by pyrochemiluminescence (16) with the Antek nitrogen analyzer system (15).

Data analysis

Analysis of variance (ANOVA) was used to test for differences in subject characteristics at baseline between groups and sexes to test the hypotheses that there would be no significant differences in metabolic outcome variables between the HC and HF diet groups. We used repeated-measures ANOVA to compare the effects of the diets, which was appropriate for our crossover design because measurements were made during both diets. Main effects and interactions for diet, group (normal weight and obese), and sex were used for each ANOVA (except at baseline, which did not involve diet). Backward selection was used to test for interactions. (For example, a diet × group interaction would indicate that the diet had a different effect in normal-weight and obese subjects). Interactions were removed from the models if they were not significant. Main effects were left in all models to adjust for the imbalance in subject numbers between groups and sexes. All means were adjusted for group and sex to account for this imbalance by using general linear model least-squares means and the results are reported as least-squares means ± SEMs; $\alpha = 0.05$ was used as the cutoff for significance. Analyses were done by using PROC MIXED in SAS (version 6.12, 1997; SAS Institute Inc, Cary, NC).

RESULTS

Baseline data on the day of admission for men and women in both groups are shown in **Table 1**. The normal-weight group consisted of 8 women and 13 men and the obese group consisted of 8 women and 6 men. The normal-weight group was slightly younger than the obese group (28.3 ± 0.7 compared with 31.7 ± 0.8 y; $P = 0.003$) and there was no significant difference or interaction between men and women. By study design, the normal-weight group weighed significantly less than did the obese group (67.3 ± 3.6 compared with 99.9 ± 4.4 kg; $P < 0.0001$) and there was no significant difference or interaction between men and women. BMI was lower in normal-weight than in obese subjects, significantly more so in women. Because of their lower body mass, particularly lean mass, the normal-weight group had a significantly lower resting metabolic rate than did the obese group (6732 ± 293 compared with 8510 ± 356 kJ/d; $P = 0.0007$). The RQ at baseline (while subjects were consuming a free-living diet) was not significantly different between the normal-weight and obese groups (0.81 ± 0.01 compared with 0.78 ± 0.02, respectively). The obese group was hyperinsulinemic compared with the normal-weight group (110.5 ± 14.4 compared with 38.7 ± 12.2 pmol/L; $P = 0.0006$), but fasting serum glucose concentrations were not significantly different between the groups (normal weight: 4.8 ± 0.1 mmol/L; obese: 5.1 ± 0.1 mmol/L).

At baseline, the percentage of dietary fat intake in the normal-weight group was estimated on the basis of the Diet Habit Survey (13) to be 28 ± 1%. The weight to be maintained for the 8 normal-weight women was 57.4 ± 2.0 kg and for the 13 normal-weight men was 75.8 ± 2.3 kg. There was no significant difference between the HC and HF diets in the amount of energy required daily by normal-weight subjects to maintain weight in the week preceding the chamber stay (HC diet: 14526 ± 962 kJ/d; HF diet: 14037 ± 1029 kJ/d). Weight stability in the normal-weight subjects was achieved over each diet phase (phase 1: 58.3 ± 1.9 kg in women and 76.6 ± 2.3 kg in men; phase 2: 57.7 ± 2.0 kg in women and 76.4 ± 2.5 kg in men).

At baseline, the percentage of dietary fat intake in the obese group was estimated (13) to be 33 ± 2%. The weight to be maintained for the 8 obese women was 99.1 ± 9.9 kg and for the 6 obese men was 99.1 ± 6.4 kg. There was no significant difference between the HC and HF diet groups in the amount of energy required daily by obese subjects to maintain weight in the week preceding the chamber stay (HC diet: 14510 ± 1050 kJ/d; HF diet: 14569 ± 1188 kJ/d). Weight stability was achieved by the obese subjects over each diet phase (phase 1: 99.5 ± 9.7 kg in women and 100.1 ± 6.5 kg in men; phase 2: 99.7 ± 9.8 kg in women and 99.3 ± 6.5 kg in men).

Twenty-four–hour total energy and substrate intakes, expenditures, and balances are shown in **Table 2**. On the basis of two-way repeated-measures ANOVA, there were no significant interactions in expenditures and balances between the diet groups, the weight

TABLE 2
Twenty-four–hour whole-room indirect calorimeter data on day 15[1]

	HC diet	HF diet	HC − HF
Energy (kJ/d)			
Intake	13916 ± 506	13811 ± 506	105 ± 397
Expenditure	10577 ± 351	9883 ± 351	695 ± 331[2]
Balance	3339 ± 565	3929 ± 565	−590 ± 481
Fat (kJ/d)			
Intake	3615 ± 222	6937 ± 222	−3322 ± 230[3]
Expenditure	3648 ± 418	5180 ± 418	−1536 ± 469[4]
Balance	–63 ± 510	1791 ± 510	−1854 ± 519[5]
Carbohydrate (kJ/d)			
Intake	7619 ± 218	4205 ± 218	3414 ± 197[3]
Expenditure	5155 ± 343	2929 ± 343	2226 ± 435[3]
Balance	2498 ± 301	1243 ± 301	1255 ± 397[6]
Protein (kJ/d)			
Intake	2682 ± 100	2669 ± 100	13 ± 75
Expenditure	1761 ± 92	1791 ± 92	−29 ± 79
Balance	904 ± 96	895 ± 96	8 ± 84
RMR (kJ/d)	7397 ± 230	7393 ± 230	4 ± 167
RQ	0.87 ± 0.01	0.82 ± 0.01	0.05 ± 0.01[3]

[1] Least-squares means ± SEM; n = 35. HC, high-carbohydrate diet (55% of energy as carbohydrate); HF, high-fat diet (50% of energy as fat); RMR, resting metabolic rate; RQ, respiratory quotient (carbon dioxide production/oxygen consumption). To convert kJ/d to kcal/d, divide by 4.184.
[2] $P = 0.0434$.
[3] $P = 0.0001$.
[4] $P = 0.0025$.
[5] $P = 0.0011$.
[6] $P = 0.0032$.

groups, or sex, except for protein expenditure (diet × group interaction, $P = 0.03$). This finding indicated little or no difference in responses to the HC and HF diets by the obese and normal-weight subjects or by men and women. (When substrate intake data and sex were compared and analyzed, a significant interaction was noted for fat and carbohydrate intakes, but this was a result of the study design and not a result of the outcomes; therefore, the interaction was not of direct interest and was not discussed further.) Therefore, the diet effects for men and women and for normal-weight and obese subjects were combined. Means for the HC and HF diets were adjusted for group and sex to account for the imbalance in the numbers of subjects.

By day 15 of both diets, subjects were in positive energy balance (Table 2, **Figure 1**) because they were sedentary during the chamber stay (HC and HF diet: $P = 0.0001$). There was no significant difference in energy balance between the diet groups (Figure 1). By design, fat intake was greater during the HF diet than during the HC diet. Fat expenditure and fat balance were also greater during the HF diet than during the HC diet. Carbohydrate intake, expenditure, and balance were greater during the HC diet than during the HF diet. The differences in expenditures of carbohydrate and fat were consistent with the observed differences in 24-h RQ. No significant differences in protein expenditure or balance were noted between diet groups.

After the combination of the HC diet and physical inactivity, ≈50% of the subjects were in positive fat balance and ≈50% were in negative fat balance (**Figure 2**). After the combination of the HF diet and physical inactivity, ≈80% of all subjects were in positive fat balance.

The 24-h resting metabolic rate was not significantly different between diet groups. There was a marginally significantly lower 24-h EE after the HF diet than after the HC diet. When differences in EI between the diet groups were accounted for, there was no significant difference in 24-h energy balance between the diet groups. Thus, the highly significant difference in carbohydrate and fat balances between the 2 diet groups did not carry over into significant differences in 24-h energy balance.

DISCUSSION

The results of the present study indicate the importance of considering the potential interaction of diet composition and physical activity in the development and maintenance of obesity. Most previous research focused exclusively on the effects of one type of diet or of physical activity (18) or examined diet composition and physical inactivity independently, but few studies compared the effects of a combination of a high-carbohydrate or high-fat diet and physical inactivity. Whether or not the consumption of a high-fat diet increases the risk of obesity depends, in part, on the pattern of physical activity. Conversely, whether physical inactivity increases the risk of obesity depends, in part, on diet composition. A better understanding of these 2 factors—physical activity and diet composition—and their relation may help explain why obesity is so prevalent in the Western world, while allowing for the fact that not everyone within that environment is obese.

The pattern examined in the present study (ie, maintenance of the usual physical activity level for 2 wk followed by 1 d of inactivity) is common in US adults and may contribute to cumulative weight gain over the adult life span. In most people, obesity develops slowly over time. Smith et al (18) showed that during 4 d of physical inactivity, normal-weight individuals maintained a positive fat balance with each day of inactivity. In the present study, there was a net increase in fat balance of 1853 kJ (443 kcal)/d, or ≈50 g. Thus, 2 d of inactivity per month would result in a fat gain of >1.13 kg (2.5 lbs)/y. It is important to note that some subjects in the present study showed a positive fat balance even when ingesting the HC diet. However, the likelihood

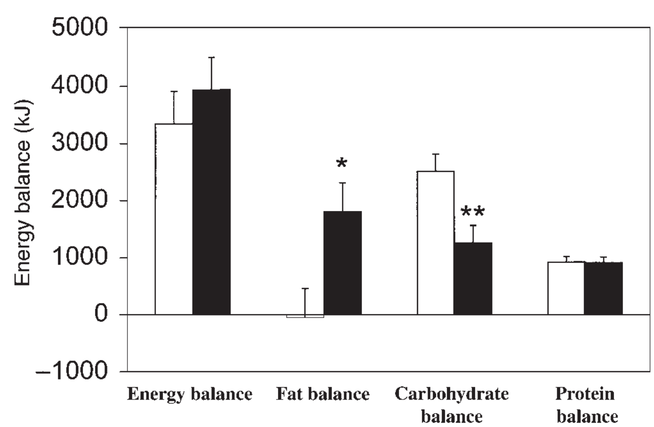

FIGURE 1. Total energy, fat, carbohydrate, and protein balances in obese and normal-weight subjects after a 23-h stay in a whole-room calorimeter (extrapolated to 24 h), during which subjects were physically inactive. Calorimetry measurements were performed on day 14 of a high-carbohydrate diet (□) and of a high-fat diet (■); no physical activity restrictions were imposed during either diet. n = 35. *,**Significantly different from the HC diet: *$P = 0.0011$, **$P = 0.0032$.

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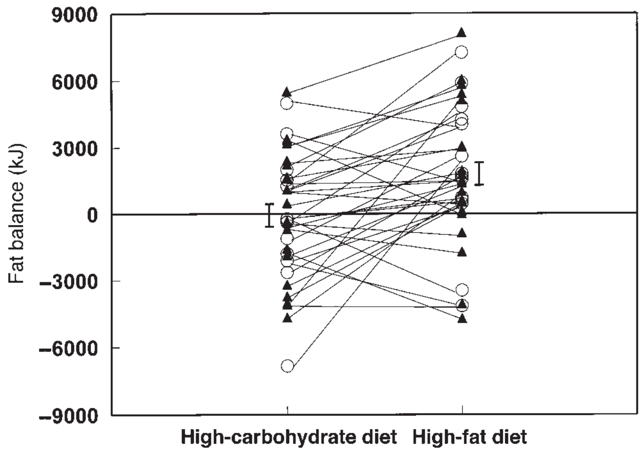

FIGURE 2. Fat balance in obese (○) and normal-weight (▲) subjects after a 23-h stay in a whole-room calorimeter (extrapolated to 24 h), during which subjects were physically inactive. Calorimetry measurements were performed on day 14 of a high-carbohydrate diet and of a high-fat diet; no physical activity restrictions were imposed during either diet. *n* = 35.

of a resultant positive fat balance was much greater with the combination of physical inactivity and the HF diet than with the combination of inactivity and the HC diet (Figure 2).

A high-fat diet is considered to be obesity-promoting only if it promotes or produces positive energy and fat balances. The results of the present study indicate that a high-fat diet can influence fat balance produced by a day of physical inactivity more than can a high-carbohydrate diet. Other studies suggest that consumption of a high-fat diet can actually lead to positive energy balance by increasing the incidence of overeating (3, 5, 7, 12). Because both the HC and HF diets in the present study were isoenergetic, energy balance did not differ significantly. It appears that the chances of being in positive energy balance may be greater when the diet consumed chronically is high in fat rather than high in carbohydrate. Although not tested in this study, diet composition may be a less important determinant of body weight in subjects who engage in a pattern of regular daily physical activity than is commonly thought. In the study by Smith et al (18), normal-weight persons who maintained a high-fat diet (50% of energy as fat) and either a high or low physical activity level had a positive fat balance on day 1 of physical inactivity, which continued and actually increased by day 4. However, fat balance decreased on day 1 of physical inactivity and then increased over the next 4 d. Although the results of Smith et al on day 1 of physical inactivity are similar to those in the present study, Smith et al did not compare the effects of a high-fat and high-carbohydrate diet in combination with physical inactivity.

The practical implication of our results is based on some assumptions. Subjects were fed the same amount of energy in the calorimetry chamber that they had consumed on each of the prior 7 d. This was done because human subjects may not reduce food intake to compensate for low levels of physical activity on a single day. However, this remains to be tested experimentally. In addition, it was assumed that fat balance measured in the calorimeter might predict subsequent accumulation of body fat mass. This issue was addressed previously (12, 15) and it is reasonable to assume that diets that promote the occurrence of days with a positive fat balance may, in the long run, produce increases in body fat mass. This excess body fat would remain until a period of negative fat balance ensued, ie, expenditure of excess body fat. Finally, it was assumed that a day of positive fat balance would ultimately lead to a more permanent increase in body fat mass than would a similar duration of positive carbohydrate balance (10, 12, 19–22).

The normal-weight and obese subjects in the present study responded similarly to changes in diet composition and to the combination of physical inactivity and diet composition. This suggests that the effects of the environment on body weight regulation were similar in normal-weight and obese subjects. Despite this similarity, the variability in responsiveness of fat balance to both the HF and HC diets suggests that some subjects might be more prone than others to gain fat mass. This propensity for increased fat mass during consumption of the HF diet may be further substantiated by the fact that fat expenditure was significantly lower during the HF than during the HC diet. Interestingly, in the physically inactive normal-weight subjects of Smith et al (18), the gradual daily increases in fat expenditure over a 4-d period were insufficient to prevent daily positive fat balances from occurring.

In summary, the data from the present study indicate that a typical pattern of consumption of an HF diet coupled with an occasional day of physical inactivity may be highly conducive to storage of body fat and, therefore, could be an important contributor to increases in body weight in adults. It should be emphasized that neither chronic consumption of a high-fat diet nor physical inactivity alone necessarily leads to obesity. Rather, each increases the probability that positive energy balance and weight gain will occur. These results suggest that the combination of a high-fat diet and physical inactivity is more likely to lead to obesity than is the combination of a high-carbohydrate (low-fat) diet and physical inactivity. These data support the need for interventions to reduce dietary fat and increase physical activity to prevent obesity.

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