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Alteration of Dietary Fat Intake to Prevent Weight Gain: Jayhawk Observed Eating Trial

Joseph E. Donnelly[1], Debra K. Sullivan[2], Bryan K. Smith[1], Dennis J. Jacobsen[3], Richard A. Washburn[1], Susan L. Johnson[4], James O. Hill[5], Matthew S. Mayo[6], Kendra R. Spaeth[2] and Cheryl Gibson[7]

Objective: To examine the effects of ad libitum diets with three distinct levels of fat intake for the prevention of weight gain in sedentary, normal-weight and overweight men and women.

Methods and Procedures: Three hundred and five participants were randomized to one of three diets. The diets targeted <25% of energy from fat (low fat (LF)), between 28 and 32% of energy from fat (moderate fat (MF)), or >35% of energy from fat (high fat (HF)). Participants consumed two meals per day on weekdays and one meal per day on weekends in a university cafeteria over a 12-week period. Energy and nutrient content of cafeteria foods were measured by digital photography. All meals and snacks consumed outside the cafeteria were measured by dietary recall. All analysis of energy and nutrient content was completed using Nutrition Data System for Research (NDS-R) version 2005.

Results: Two hundred and sixty participants completed the study. LF gained 0.1 ± 3.1 kg, MF gained 0.8 ± 2.5 kg, and HF gained 1.0 ± 2.2 kg and there was no gender or age effect. Longitudinal mixed modeling indicated a significant difference among the groups in weight over time (P = 0.0366). When adjusting for total energy intake, which was a significant predictor of weight over time, the global effect for the group was eliminated. Thus, increasing weight was a function of increasing energy but not increasing percentage of fat intake.

Discussion: Energy intake, but not percentage of energy from fat, appears responsible for the observed weight gain. LF diets may contribute to weight maintenance and HF diets may promote weight gain due to the influence of fat intake on total energy intake.

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INTRODUCTION

Approximately 66.3% of the adult population in the United States is overweight or obese (1). Overweight and obesity are associated with increased mortality risk (2,3) and with the development of numerous comorbidities (4,5). Additionally, overweight and obesity in adults are also associated with increased health care utilization and costs (6,7).

In the attempt to diminish overweight and obesity, numerous combinations of energy restriction and physical activity have been investigated and have shown moderate short-term success for the reduction of body weight (8–11). However, 50% of individuals who initially lose weight will regain 45–75% of the weight in 12–30 months from the end of treatment (12,13). This reality provides a strong rationale for investigating strategies aimed at the prevention of obesity.

One potential strategy for prevention of weight gain is to reduce dietary fat intake. A higher percentage of total energy intake from dietary fat has been associated with increased energy intake, higher BMI, and increased risk for overweight and obesity (14–16). It has also been demonstrated that individuals who are successful in preventing weight regain after weight loss consume a lower fat diet (17–19). While few studies have been specifically designed to determine the long-term effects of low-fat (LF) diets on prevention of obesity, results from the Pound of Prevention Study (20) showed a positive relationship between the inability to maintain body weight and dietary fat intake over 3 years (20). Results from The Women's Health Initiative Dietary Modification Trial (21) indicated that LF diets are effective for weight maintenance over 7.5 years.

[1]Energy Balance Laboratory and Center for Physical Activity, Nutrition, and Weight Management, Schiefelbusch Institute for Lifespan Studies, University of Kansas, Lawrence, Kansas, USA; [2]Department of Dietetics and Nutrition, University of Kansas Medical Center, Kansas City, Kansas, USA; [3]Global Medical Affairs, Schering-Plough Pharmaceuticals, Kennilworth, New Jersey, USA; [4]Department of Pediatrics, University of Colorado Health Sciences Center, Denver, Colorado, USA; [5]Center for Human Nutrition, University of Colorado Health Sciences Center, Denver, Colorado, USA; [6]Department of Biostatistics, University of Kansas School of Medicine, Kansas City, Kansas, USA; [7]Department of Internal Medicine, University of Kansas Medical Center, Kansas City, Kansas, USA. Correspondence: Joseph E. Donnelly (Jdonnelly@ku.edu)

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The influence of level of fat may be due to the impact of dietary fat on increased energy intake. This is illustrated by Donahoo *et al.* (14), who studied energy intake over dietary fat levels from 25 to 40% energy from fat and found that energy intake increased as dietary fat increased. The results indicated that energy intake would increase by ~20 kcal/day with each 1% increase in percentage of fat in the diet from 25 to 40%.

Although the above studies suggest energy from fat rather than fat *per se* lead to increases in weight, this remains controversial. For example, Bray *et al.* (22), have argued that high fat (HF) diets are energy dense and therefore contribute to weight gain while Willett *et al.* (23), have indicated there is little association of fat intake with changes in weight and this conclusion was also recently reported by Field *et al.*, in an 8-year follow-up investigation of the Nurses' Health Study (24). Although longitudinal prospective studies and cross-sectional observational studies provide some insight into this controversy, there have been no adequately powered, randomized trials with rigorous documentation of energy and macronutrient content to clarify the issue of prevention of weight gain due to the energy from fat or fat *per se*.

The intent of the present study was to assess the impact of different levels of dietary fat in free-living subjects eating ad libitum while assuring documentation of compliance to the prescribed dietary fat levels. To this end, we chose a randomized design, direct observation of energy intake, and continuous measures of dietary compliance. We hypothesized that individuals who received lower fat diets would gain less weight than individuals who received higher fat diets and that weight would be related to the level of energy associated with fat intake and not fat *per se*.

METHODS AND PROCEDURES

Overview of intervention

This intervention was termed "The Jayhawk Observed Eating Trial" and was designed as a 12-week, randomized, efficacy trial. Participants were randomly assigned to one of three levels of dietary fat intake for 12 weeks. The quantity and types of foods consumed in the university cafeteria were measured using digital photography and foods consumed outside the cafeteria by recall. Energy and macronutrient composition were assessed using Nutrition Data System for Research (NDS-R) version 2005 (University of Minnesota, Minneapolis, MN). Dietary fat intake comprised <25% energy as fat (LF), 28–32% energy as fat (moderate fat (MF)), or >35% energy as fat (HF) for the three groups. Participants were instructed to consume foods that fit in with their assigned dietary fat intake.

Participants

This project was completed at The University of Kansas with university students who were compensated for their participation. Potential participants underwent initial eligibility screening by telephone or by completing an initial eligibility survey on the Jayhawk Observed Eating Trial study website. After initial screening, potential participants attended a consent meeting, had their questions answered, and signed the consent document. A baseline physical exam by a licensed physician and board certified Bariatrician was performed on all participants. Eligibility criteria included age: ≥17, BMI: 22–29.9, weight stable (±2.27 kg) for 12 weeks prior to intake as judged by their health history taken at the time of baseline physical exam, general good health, free from cardiovascular disease, hypertension, metabolic disorders (i.e., diabetes, thyroid disease), no tobacco use, fewer than three drinks of alcohol per day, sedentary (<500 kcal/week of exercise energy expenditure (walking, jogging/running, weight training)) as assessed by a modified Minnesota Leisure Time Physical Activity Questionnaire (25), absence of eating disorders (26), absence of clinical depression (27), not using special diets, no food allergies, and habitual fat intake between 20 and 50% total calories as assessed by The National Cancer Institute's fat screener (28). A summary of recruitment and participation is shown in **Figure 1**.

Random group assignment and informed consent

Participants were randomized to LF, MF, or HF groups, stratified by gender, using a 1:1:1 ratio under the supervision of the project statistician (M.S.M.). Potential participants were informed that the purpose of the project was to investigate the impact of dietary composition on the immune system (sham). The true purpose of the study was not revealed to participants to decrease potential reactivity associated with preconceived notions regarding the effect of the level of fat intake on body weight. All participants gave informed consent before participating in any aspect of the investigation. Approval for the study was obtained from the Human Subjects Committee at The University of Kansas.

Nutrition education and dietary procedures

Each participant received nutrition education provided by a registered dietitian regarding appropriate foods that met the participant's assigned dietary fat group. Nutrition education was provided in a single, 60-min lecture/discussion session. Participants were also given a pamphlet listing cafeteria foods and other commonly consumed foods that were color coded by dietary fat levels. During the intervention, additional counseling was given to any individual who did not consume their assigned level of dietary fat during the previous week. To facilitate the identification of foods and beverages shown in digital photographs (described below), participants were trained during baseline eating

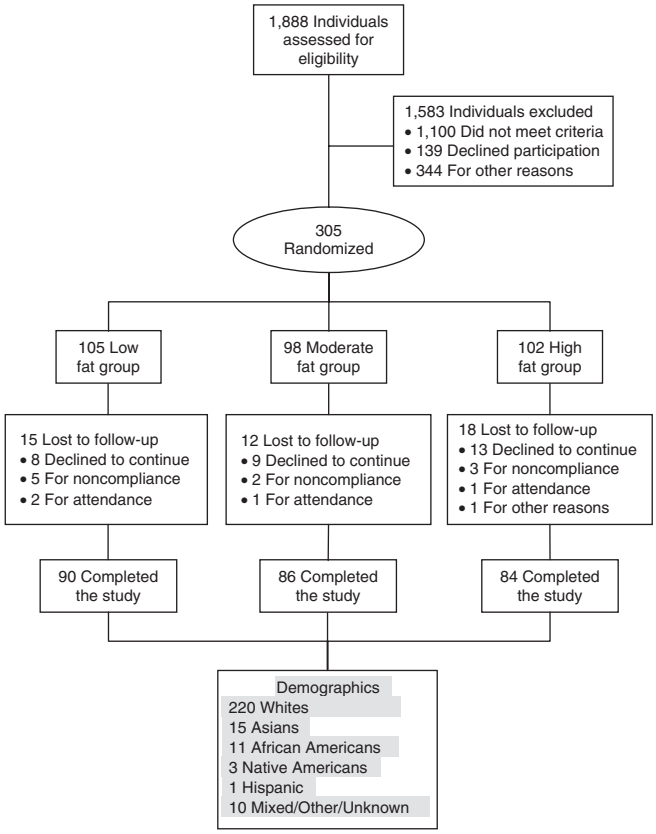

Figure 1 Participant flow through the study.

regarding placement of these items on their trays. For example, items in a mixed salad were separated on a plate rather than mixed together and condiments were placed in a separate bowl, etc. Participants were also instructed how to keep details for foods consumed outside of the cafeteria so they could accurately report intake during diet recalls (described below).

Cafeteria

Participants consumed their meals in the university cafeteria. Participants obtained a menu from the cafeteria research staff that listed all foods that were served at that meal and the color code for each item. Utilizing this menu, the participants selected appropriate food items according to their dietary fat group and reported to the research site to consume their meal.

The cafeteria served 8–10 entrees per meal and also provided a large variety of items such as sandwiches, grill items, ethnic foods, a large salad bar, beverage bar, and a variety of dessert items. The menu for each semester (a 4-week cycle menu) was obtained from the university cafeteria staff before each semester; thus, research staff were able to obtain the recipes for any new items. Standard portion sizes, either by weight or serving spoon, were served by university cafeteria staff and self-portioned items were served using standard serving spoons.

Documentation of dietary intake using digital photography and diet recalls

The food items selected by the participants were photographed prior to consumption and again after consumption. This procedure has been successfully used by others (29) and is analogous to visual observation (30) and we have termed it "picture plate waste" (PPW). The PPW technique required the participant to place their cafeteria tray in a holding area that assured consistent position and distance between the tray and the digital camera (Olympus C4000) used to photograph the foods. Two photographs were taken before and after meals. One photograph was taken at a 90° angle above the tray and one photograph was taken at a 45° angle to maximize depth perception and identification of food and beverage items. Research staff wrote the date, meal (i.e., lunch), participant identification number, and when necessary, food description (i.e., skim vs. whole milk) on a small card and the card was placed on the food tray and photographed. Dietary intake was assessed by a combination of PPW and dietary recall to total a 24-h period for the duration of the study. PPW was completed for a minimum of two meals per day on weekdays and one meal per day on weekends. Multiple-pass diet recalls were conducted at each meal to capture items consumed since the last cafeteria visit.

Nutrient analysis of dietary data obtained by PPW and recall (for the total 24-h period), was completed for 4 random days (3 week days and 1 weekend day) during each week of the study. Energy and macronutrient content of the diets were calculated using NDS-R (version 2005).

Staff training, validity and reliability of dietary assessments

All dietary intake staff received three, 3-h training sessions, conducted by the supervising dietitian on procedures for obtaining PPW, dietary recalls, PPW visual estimation, and NDS-R coding. In order to be certified to work, each individual had to demonstrate a standard of 90% accuracy with the respective techniques. Accuracy for diet recalls was determined by comparison of results to the supervising registered dietitian, and NDS-R coding and measured food items for PPW.

Dietary adherence

Dietary fat consumption was determined on 4 random days (3 weekdays, 1 weekend day) each week to evaluate compliance with the assigned dietary fat group. If a participant did not adhere to their dietary fat group requirements for 3 weeks over the course of the 12-week intervention, they were removed from the study. Additionally, participants were removed if they failed to consume meals at the cafeteria for 90% of the scheduled meals.

Body weight, BMI, and body composition

Body weight was measured at baseline, 6, and 12 weeks between 7 AM and 9 AM. Participants wore a standard hospital gown and were weighed on a calibrated digital scale accurate to +0.1 kg (Model #PS6600; Befour, Saukville, WI). Subsequently, height was measured using a stadiometer (Perspective Enterprises, Portage, MI). Dual energy X-ray absorptiometry (Lunar DPX,-IQ; GE Medical Systems, Madison, WI) was used at baseline and 12 weeks to determine fat-free mass, fat mass, and percent body fat.

Leisure time physical activity

A modification of the Minnesota Leisure Time Physical Activity Questionnaire (25) was administered at baseline, 6, and 12 weeks to document habitual leisure time physical activity. Participants reported the number of days/week and min/day that they engaged in sport and leisure time physical activities during a typical week over the past 2 months at baseline and over the past 2 weeks at 6 and 12 weeks.

Immune questionnaire (Sham)

The immune questionnaire was constructed by the investigators using information from a variety of published sources (31,32) and contained 26 different illnesses. The illnesses varied from minor (i.e., cough, acne, lack of appetite, etc.) to major (i.e., lung infection, depression, bladder infection, etc.). Participants also were asked to report any medication use, reason for use, and the dosage of each medication. Finally, participants were asked if they had seen a physician in the past week. If they had, they were asked to state the reason of the visit.

Blinding

Research assistants in the cafeteria were not blinded regarding the participant's diet group; this was considered impractical since their responsibility was to encourage the participant to consume the appropriate diet. Research assistants who performed laboratory testing (i.e., height, weight, dual energy X-ray absorptiometry) and diet analysis (PPW, NDS-R) were blinded to the group assignment of the participants.

Statistical analysis

This was an efficacy study; therefore, analyses were performed on participants who completed the entire 12-week study and all associated laboratory testing. Prior to study initiation, a sample size of 252 completers was determined so as to achieve 80% power with a Type 1 error rate of 0.0167 (so as to detect an effect size of 0.5 s.d. for any pairwise comparisons for the primary endpoint of body weight). This conservative adjustment was made to assure an overall type I error rate of no greater than 5% since three pairwise comparisons were of interest. Two hundred and sixty individuals completed the study; therefore, we had adequate power for this study. Our primary endpoint was the longitudinal comparison of weight across the three groups post baseline, adjusted for the baseline weight using linear mixed models. This approach utilizes more information and provides greater power than assessing change in weight from baseline to 12 weeks (33). We also compared change in weight from baseline to 12 weeks across the three groups using a one-way analysis of variance. We subsequently used paired *t*-tests to determine if changes in weight within groups from baseline to 12 weeks were significant.

Descriptive statistics (mean ± s.d.) were calculated at each assessment period for all dependent measures. ANOVA was used to compare any differences in the average percent fat intake and the average total energy intake throughout the study across the three dietary fat groups. In the longitudinal models, we compared weight across the three groups over time adjusting for baseline weight as a covariate. A global test for group effect was performed with a Type I error rate of 5%. If this was significant then pairwise comparisons were performed and a Type I error rate of 1.67% was used for significance for all pairwise comparisons. We used linear mixed models to adjust for the average percent fat intake and average total energy intake throughout the study to assess the effect of these

variables on weight and to determine whether they attenuated the effect of treatment as well as to assess whether there were any effects due to gender or age. Similar analysis was performed on BMI and body fat percentage. We examined first order autoregressive and unstructured correlation structures for the repeated measures and found that the unstructured correlation structure minimized the Akaike Information Criterion and Bayesian Information Criterion and thus was chosen for the models. All analyses were performed using SAS software version 9.1 (SAS Institute, Cary, NC).

RESULTS

Participants

Three hundred and five individuals were initially randomized to one of three dietary fat groups and 260 (85%) completed the entire study (Figure 1). There were no significant differences at baseline between participants who completed the study and non-completers for age, body weight, BMI, percentage of body fat, or energy intake and macronutrient composition ($P > 0.05$). No significant differences at baseline existed for participants in the three dietary fat groups (Table 1). At baseline, 168 individuals were of normal weight (BMI < 25), 82 were overweight (BMI between 25 and 29.9), and 10 were obese (BMI > 30).

Adherence to cafeteria meal consumption and dietary fat group

Participants consumed an average of 124 ± 10 meals at the research site, which represented 94.7% of the required meals and percentage of meals did not differ between dietary fat groups ($P > 0.05$). Participants in LF consumed 20.4 ± 3.5% fat, MF consumed 30.7 ± 2.3% fat, and HF consumed 40.3 ± 3.2% fat (Table 2, $P < 0.0001$).

Energy intake

One-way ANOVA indicated that there were statistically significant differences between diet groups for average daily energy intake (LF = 1963 ± 451 kcal, MF = 2328 ± 481 kcal, HF = 2513 ± 545 kcal ($P < 0.0001$). Pairwise comparisons indicated that differences in energy intake between all three diet groups were statistically significant (Table 2, $P = 0.0001$).

Physical activity

Physical activity measured by Minnesota Leisure Time Physical Activity Questionnaire indicated the participants were sedentary at baseline with an exercise energy expenditure of 230 ± 370 kcal/week. There were no significant differences for total leisure time physical activity between groups at baseline, 6, or 12 weeks.

Body weight, BMI, and body composition

Change in weight of 0.1 ± 3.1 kg from baseline for LF was not significant however; significant gains of 0.8 ± 2.5 kg were shown for MF ($P = 0.009$) and 1.0 ± 2.2 kg for HF (Table 3, $P = 0.0002$). Our primary analysis using mixed linear models showed a global difference among the dietary fat groups for weight over time controlling for baseline weight (Table 3, $P = 0.0366$). None of the pairwise comparisons met the conservative significance level of 0.0167; however, the difference between LF and HF groups had a P value of 0.0193. Given the global effect of the dietary fat group on body weight, and the observed differences in total energy intake across the three fat groups, a mixed linear model was used that included the average total energy intake of each individual over the study period. When average total energy intake of each individual over 12 weeks was included in the model it was significant ($P = 0.0025$) and eliminated the global effect of the groups on weight (Table 4). This indicated that increasing weight was a function of total energy intake, not percentage of fat consumption. As shown in Table 4, the negative estimates for each group are due to the collinearity with total energy intake. However, there was not any significant effect because group and energy intake were highly significant predictors of weight over time. Percentage of fat intake did

Table 1 Baseline characteristics by gender and group

	Low fat		Moderate fat		High fat	
	Male (n = 55)	Female (n = 35)	Male (n = 54)	Female (n = 32)	Male (n = 54)	Female (n = 30)
Age (years)	19.1 ± 1.4	18.6 ± 0.7	19.1 ± 1.4	18.5 ± 0.7	19.1 ± 1.3	18.6 ± 0.9
Weight (kg)	78.9 ± 9.3	67.1 ± 9.0	79.4 ± 10.9	66.4 ± 7.8	79.7 ± 9.0	64.3 ± 7.0
BMI (kg/m^2)	25.0 ± 2.7	24.2 ± 2.7	24.6 ± 2.6	24.3 ± 2.5	25.1 ± 2.4	23.4 ± 1.8
Body fat (%)	22.9 ± 8.2	34.8 ± 6.5	21.9 ± 8.0	34.7 ± 5.6	21.4 ± 7.2	33.3 ± 5.1

Values are means ± s.d. There were no significant differences between groups for either gender.

Table 2 Daily dietary intakes by group

	Low fat (n = 90)		Moderate fat (n = 86)		High fat (n = 84)	
	Baseline	Intervention	Baseline	Intervention	Baseline	Intervention
Kcal/day	2,446 ± 626	1963 ± 451[a]	2,502 ± 664	2,328 ± 481[b]	2,526 ± 689	2513 ± 545[c]
% FAT	34.5 ± 5.9	20.4 ± 3.5[a]	35.2 ± 5.4	30.7 ± 2.3[b]	34.3 ± 4.7	40.3 ± 3.2[c]
% CHO	51.1 ± 6.9	64.7 ± 4.6[a]	49.6 ± 6.2	54.3 ± 3.5[b]	50.7 ± 6.0	44.2 ± 4.1[c]
% PRO	14.4 ± 2.9	14.9 ± 3.1	15.2 ± 2.9	15.0 ± 2.5	15.0 ± 3.1	15.5 ± 2.3

Values are means ± s.d. At baseline, there were no significant differences between groups for any of the dietary variables. Intervention values with different letters are significantly different between groups ($P < 0.05$).
CHO, carbohydrate; FAT, fat; PRO, protien.

Table 3 Anthropometric changes across time by group

	Baseline	6 weeks	12 weeks
Low fat (n = 90)			
Weight (kg)	74.3 ± 10.8	74.1 ± 10.3	74.4 ± 10.4
BMI (kg/m^2)	24.7 ± 2.7	24.6 ± 2.6	24.7 ± 2.7
Body fat (%)	27.4 ± 9.5	NA	27.2 ± 9.6
Moderate fat (n = 86)			
Weight (kg)	74.5 ± 11.7	74.9 ± 11.7	75.3 ± 11.9
BMI (kg/m^2)	24.4 ± 2.6	24.5 ± 2.6	24.7 ± 2.8
Body fat (%)	26.9 ± 9.5	NA	27.3 ± 9.6
High fat (n = 84)			
Weight (kg)	74.2 ± 11.1	74.7 ± 11.1	75.2 ± 11.4
BMI (kg/m^2)	24.5 ± 2.3	24.6 ± 2.4	24.8 ± 2.5
Body fat (%)	25.7 ± 8.7	NA	26.4 ± 8.8

Values are means ± s.d. Mixed linear modeling showed global differences among groups for body weight over time after controlling for baseline weight (P = 0.0366). Mixed linear modeling did not show differences between the groups over time for BMI or percentage of body fat.
NA, not assessed.

Table 4 Summary of linear mixed model

	Model without energy intake		Model with energy intake	
Variable	Estimate (s.e.)	P value	Estimate (s.e.)	P value
Intercept	1.94 (0.79)	0.0145	1.19 (0.81)	0.1420
Group	—	0.0366	—	0.5523
High Fat	0.08 (0.28)		–0.06 (0.28)	—
(Reference) Moderate fat	—		—	—
Low fat	–0.56 (0.27)		–0.30 (0.28)	—
Baseline weight in kg	0.97 (0.01)	0.0001	0.96 (0.01)	0.0001
Period	0.33 (0.09)	0.0004	0.33 (0.09)	0.0004
Energy intake	NA		0.0008 (0.0002)	0.0025

Summary and comparison of parameter estimates (s.e.) and P values for linear mixed models of weight over time with group, baseline weight and period as covariates without and with average energy intake as a covariate.

not have a significant effect on weight when included alone or in conjunction with total energy intake. There was no effect of age, gender, or physical activity when included in any of the linear mixed models. For BMI and percentage of body fat, linear mixed models did not indicate that the differences between the groups were significant.

DISCUSSION

The results from the current study suggest that HF diets promote increased energy intake and lead to weight gain when consumed ad libitum in free-living subjects. Results from other studies have reported that HF diets increase energy intake and could lead to weight gain (14,34,35). Consuming a diet that contains <25% fat vs. higher levels of fat might be a useful strategy to help individuals and the population at large avoid the gradual increase in body weight that most people experience. Consuming diets lower in fat as a strategy to prevent weight gain would be in accordance with most public health guidelines (36).

The effect of the level of dietary fat on energy intake and weight gain was as hypothesized across the three dietary fat groups. That is, as dietary fat and total energy intake increased, body weight increased. The diminished weight gain shown by the groups with the lower dietary fat intake indicates that reduced fat diets may be an effective intervention strategy to prevent weight gain in at-risk populations (37). To illustrate the potential clinical significance, if the increases for body weight shown in the present study were extrapolated from 12 to 52 weeks the difference in weight gain would be >3.6 kg between the LF and HF groups.

Findings from the present study indicate that the primary impact of dietary fat level was on total energy intake. As the percentage of fat in the diet increased, participants consumed more total energy. Percentage of energy from dietary fat had no additional impact on weight over time after accounting for energy intake. This is an important finding since good tasting, HF, energy dense foods are widely available and may contribute toward "passive over-consumption" by increasing the energy value of many foods.

In un-supervised studies in free-living subjects it is difficult to separate the effects of diet composition from the effects of non-adherence to the diet recommendations. Underestimation and reporting of dietary intake is so pervasive, it is assumed to be present in virtually all diet studies using free-living individuals (38), and was likely to occur in the current study. For example, energy intake decreased slightly from baseline to intervention for LF, yet this group did not lose weight. The discrepancy is likely due to the information provided from diet recalls, as a major strength of the present study was the careful attention to dietary compliance in the cafeteria. The participants ate ~95% of offered cafeteria meals under supervision, showed remarkable compliance with the intended percentage of dietary fat as per their group assignment, and showed ~10% separation for dietary fat intake. In turn, this allowed us to examine the role of dietary fat on weight and provided a reasonable measure of confidence that the outcomes were in response to the level of dietary fat intake.

In free-living, previously sedentary, university students, body weight increased with increased dietary fat consumption. The effect of dietary fat was seen through an increase in energy consumption and not in the level of fat *per se*. Students who consumed more fat consumed more total energy and had greater body weight at 12 weeks compared to those who consumed lower fat diets and less total energy. HF diets contribute to weight gain by increasing energy intake and LF diets can help prevent weight gain by decreasing energy intake. Reduction of fat intake appears to be a viable strategy to prevent weight gain when energy intake is ad libitum.

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DISCLOSURE

The authors declared no conflict of interest.

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