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Metabolic responses to dietary fatty acids in obese women

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HIGHLIGHTS

- High fat meals rich in either MUFAs, PUFAs, or SFAs did not differentially affect the thermic effect of the meal.
- Postprandial fat oxidation did not differ between 3 different high-fat meals.
- Obese women show similar metabolic responses to SFA, MUFA, and PUFA-rich meals.

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ABSTRACT

Background: The composition of fatty acids in a diet may differentially affect metabolism, thus playing a role in the development of obesity. Our purpose was to study the effects of three high-fat (HF) meals with different dietary fatty acid compositions on the thermic effect of meal (TEM) and substrate oxidation in obese premenopausal women.

Methods: 16 healthy obese women, aged 18–39 years, participated in a single-blinded randomized cross-over study, in which they consumed isocaloric HF meals (70% of energy from fat) rich in either saturated fat (SFA), monounsaturated fat (MUFA) or polyunsaturated fat (PUFA). Indirect calorimetry was used to measure respiratory gases for a 5-hour postprandial period. Data collected was used to determine respiratory exchange ratio (RER) for assessing substrate oxidation, and energy expenditure for the determination of TEM.

Results: There was a significant time effect on both substrate oxidation and TEM ($p < 0.05$). With and without using RMR as a covariate, there were no significant differences in TEM between test meals (TEM of 10.8 ± 0.8 vs 11.0 ± 1.0 kcal $*$ 5 h for high-MUFA vs. high-SFA meals, respectively, $p = 0.06$). No treatment difference was found for postprandial substrate utilization (4.9 ± 0.4, 4.9 ± 0.3 and 4.6 ± 0.4 g of fat oxidation following SFA, MUFA, and PUFA-rich HF meals, respectively; 13.2 ± 0.9, 13.3 ± 0.5 and 13.9 ± 0.6 g of carbohydrate oxidation following SFA, MUFA, and PUFA-rich HF meals, respectively).

Conclusions: In premenopausal obese women, HF meals rich in either MUFAs, PUFAs, or SFAs did not differentially affect TEM or postprandial substrate oxidation.

1. Introduction

There is a positive association between dietary fat intake and the development of obesity [1,2]. More recently, studies have been done to look at differential effects of dietary fatty acid composition on weight gain and prevalence of obesity. An inverse relationship between mono-unsaturated fatty acid (MUFA) intake and weight gain has been reported in the Nurses' Health Study and the "Seguimiento Universidad de Navarra" (SUN) Project [3,4]. Meanwhile, a positive correlation between the prevalence of obesity and the availability of saturated fatty acids (SFA) and unexpectedly, polyunsaturated fatty acids (PUFA), has been observed [5]. To better understand how the type of fatty acid may affect obesity risk it is important to examine acute meal and diet metabolic responses.

The effect of high-fat (HF) meals with different fatty acid compositions on metabolism has been studied in various populations. In normal weight individuals, the majority of the studies report that fat oxidation is not different following HF meals enriched in SFA, MUFA or PUFA [6–9]. With regard to energy expenditure (EE), our previous work indicated that in normal weight premenopausal women, a HF meal enriched in PUFAs elicited the greatest effect on the thermic effect of meal (TEM) compared with high MUFA or SFA meals [8]. In addition, Casas-Agustench et al. [10] reported greater TEM after high-PUFA and high-MUFA meals compared with high-SFA meal. In general, in normal

Abbreviations: HF, high fat; TEM, thermic effect of meal; ANOVA, analysis of variance; AUC, area under the curve; BMI, body mass index; EE, energy expenditure; FFM, fat free mass; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; RER, respiratory exchange ratio; RMR, resting metabolic rate; SE, standard error; SFA, Saturated fat; TFA, trans fatty acids; UCP, uncoupling protein.

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weight subjects, it appears that PUFAs and possibly MUFAs result in greater TEM, but not fat oxidation, compared with SFAs [9–11].

However, obese individuals have been shown to exhibit different metabolic responses to HF meal challenges compared with normal weight individuals [12]. To date, very few studies have been done in obese adults to compare differential metabolic responses between SFA, MUFA or PUFA enriched HF meals. Two studies reported a greater increase in fat oxidation in obese men and postmenopausal women following a HF meal enriched in olive oil (rich in MUFA) compared with a HF meal enriched in cream (rich in SFA) [12,13]. However, a study by Casas-Agustench et al. [10] showed that there is no difference in fat oxidation between different HF meals in overweight men. No data on premenopausal obese women exists.

Energy expenditure or TEM response to HF meals in premenopausal obese women has not been sufficiently studied either. Soares et al. [13] and Casas-Agustench et al. [10] reported that a HF meal enriched in unsaturated fatty acids could induce a greater TEM compared with that enriched in SFAs in postmenopausal obese women and overweight men, respectively. Flint et al. [14] however reported no difference between different HF meals. Given the limited number of studies and inconclusive results, more research on the metabolic and thermogenic responses in premenopausal obese women to different HF meals is needed. The purpose of this study was to explore the effects of three different HF meals enriched in MUFA, PUFA, or SFA on postprandial substrate oxidation and TEM in obese premenopausal females. Based on our findings in normal weight women, we hypothesized that postprandial TEM would be the highest after the PUFA meal and the lowest after the SFA meal with no differences between HF meals for substrate utilization.

2. Subjects and methods

2.1. Subject population

Sixteen healthy sedentary obese women (Body mass index (BMI) 30–40 kg/m^2), ages 18–45 years were recruited for the study. All subjects were screened before entering the study based on the following criteria. The exclusion criteria included: smoking or alcoholic or substance abuse; evidence of weight loss or gain exceeding 5% of body weight within the past 3 months; regular exercise greater than 3 h per week; plans to lose weight or begin a weight loss program between the initiation of study and final testing; BMI outside of selected range (30–40 kg/m^2); plans to begin an exercise program or change current exercise routines between the initiation of study and final testing; medications that could influence appetite or sensory function; reports of any chronic diseases including metabolic or endocrine diseases, gastrointestinal disorders, or history of medical or surgical events that could affect fat digestion and hormone signaling; any supplement use other than a daily multivitamin; or currently pregnant, lactating, or planning on becoming pregnant before the conclusion of this study. The study was approved by the Texas Tech University Human Research Protection Program and informed written consent was obtained from all subjects.

2.2. Procedures

This is a single blinded, randomized cross-over study. There were a total of three visits (for three treatment conditions) that each subject completed with at least 4 days between each visit. All subjects were tested on days 3–9 of their menstrual cycle. Those three treatment conditions were HF meals rich in either MUFAs, PUFAs, or SFAs, which were completed in a random order. Since we required at least 4 days between each visit, the participants were measured across cycles, so the 3 visits happened during a 2 or 3 month period of time (across 2 or 3 menstrual cycles). Over the course of the study, the subjects were asked to keep any physical activity pattern and dietary intake as constant as possible. On the day before each visit, the subjects were instructed to avoid any structured exercise. In addition, for lunch, dinner and an evening snack before each study visit, the subjects were asked to choose from a list of food items that were provided by research personnel. The list of food items contained 30% of energy from dietary fat. The exact same meals and snacks that they chose for the first study visit were provided at visits 2 and 3.

On the day of testing, the subjects arrived at the lab at 0700 h after an overnight fast (no food or drink except water for 8–12 h). After anthropometric measurements (height, weight and body composition), resting metabolic rate (RMR) was measured for 30 min. The Bod Pod (Cosmed USA, Inc., Concord, CA) was used to measure body composition. Indirect calorimetry was used to measure RMR using the ParvoMedics TrueOne® 2400 Canopy System (ParvoMedics, Sandy, UT) under standardized conditions. Briefly, the subjects were asked to stay awake and motionless in a supine position with a plastic hood placed over their head to measure oxygen consumed and carbon dioxide produced. Respiratory gases were used to calculate RMR using the Weir equation [15]. Calibration gas (Airgas Specialty Gases, Inc., Lenexa, KS) was used for O_2 and CO_2 analyzer calibration. This was conducted before each of the study visit and on an hourly basis during subject testing. Additionally, a 3-liter syringe flow meter was used for the calibration of flow/volume measurement before each of the study visits. After the baseline RMR measurement, an intravenous catheter was placed in the antecubital vein of the subject and a fasting/baseline blood sample was taken. The line was kept patent with 0.9% normal saline. The subject then ingested one of the HF liquid meals within a 5-minute time limit.

2.3. Liquid meals

The subject ingested a different HF liquid meal at each of the 3 study visits. The liquid meals contained the same base of 8 fl oz (237 mL) of chocolate Ensure® with soy lecithin and Nesquik® and had different dietary fatty acids added to it depending on the treatment condition. The PUFA-rich meal was "base" plus sunflower oil and flaxseed oil with 42% of total energy coming from PUFA (fatty acid chain length was majorly C18 (43%) and C16 (3%)). The MUFA-rich meal was "base" plus canola oil and extra virgin olive oil with 42% of total energy coming from MUFA (fatty acid chain length were majorly C18 (43%) and C16 (3%)). Finally, the SFA-rich meal was "base" plus butter, coconut oil, and palm oil with 40% of total energy coming from SFA (fatty acid chain length was majorly C18 (21%) and C16 (16%)). The nutrient breakdown of each HF liquid meal can be found in Tables 1, 2 and 3. The HF liquid meals were designed using Food Processor software (ESHA Research, Salem, OR). We were also unable to match all types of fatty acids between test meals because we wanted to use fats/oils that are present in the food supply to increase the clinical application. Our goal was to have 40% of total energy coming from the fatty acid of interest, have 70% of total energy derived from total fat, and keep the energy content similar. In order to meet those goals, not all of the other fatty acids were matched between each test meal.

Table 1
Liquid meal nutrient composition breakdown.

	SFA	MUFA	PUFA
Kilocalories	748.5	726.7	732.3
Kilocalories from fat	470.9	506.4	506.8
Protein (g)	9.0	9.0	9.0
Carbohydrate (g)	43.0	43.0	43.0
SFA (g)	40.4	5.6	5.5
MUFA (g)	13.2	34.3	13.0
PUFA (g)	4.6	13.0	34.4
% of total energy from fat	70.3%	69.7%	69.0%
% of energy from fatty acid of interest	40.4% SFA	42.4% MUFA	42.3% PUFA

SFA: Saturated fatty acid; MUFA: Monounsaturated fatty acid.
PUFA: Polyunsaturated fatty acid.