Nutrition 41 (2017) 14–23

Contents lists available at ScienceDirect

Nutrition

journal homepage: www.nutritionjrnl.com

Applied nutritional investigation

Hunger and satiety responses to high-fat meals after a high-polyunsaturated fat diet: A randomized trial

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ARTICLE INFO

Article history:
Received 19 December 2016
Accepted 11 March 2017

Keywords:
Ghrelin
PYY
Insulin
Leptin
PUFA
SFA
VAS

ABSTRACT

Objective: Previous studies have shown that polyunsaturated fats (PUFAs) elicit a greater response in satiety after a single-meal challenge compared with other types of fats. The long-term effects of PUFAs on satiety, however, remain unknown. The aim of this study was to determine subjective and physiological hunger and satiety responses to high-fat (HF) meals before and after a 7-d PUFA-rich diet.

Methods: Twenty-six, healthy weight (body mass index 18–24.9 kg/m^2), sedentary adults were randomly assigned to either a 7-d PUFA-rich diet (n = 8 men and n = 8 women) or a 7-d control diet (n = 5 men and n = 5 women). After a 3-d lead-in diet, participants reported for the baseline visit where anthropometrics, fasting visual analog scale (VAS) measurements, and a fasting blood sample were collected. Then, two HF meals (breakfast and lunch) were consumed. Postprandial blood draws and VAS measures were collected approximately every 30 min for 4 h after each meal, for a total of 8 h.

Results: From pre- to post-PUFA–rich diet, there was a decrease in fasting ghrelin ($P < 0.05$) and an increase in fasting peptide YY (PYY; $P < 0.05$); however, there were no changes in fasting insulin or leptin concentrations. The postprandial response for PYY was higher after the PUFA-rich diet visit compared to baseline ($P < 0.01$). However, there were no differences in the postprandial response for ghrelin, insulin, leptin, or VAS measures from pre- to post-diet in either the PUFA-rich diet or control (ns).

Conclusion: A PUFA-rich diet consumed for 7 d favorably altered fasting and postprandial physiological markers of hunger and satiety; yet, did not alter subjective ratings of hunger or fullness.

Introduction

Foods that reduce hunger or increase satiety or energy expenditure might be helpful in achieving and maintaining energy balance. Dietary fats give rise to physiological differences in whole-body metabolism with important health consequences, dependent on the amount and type of dietary fatty acids (FAs) being consumed. The increasing interests in incorporating polyunsaturated fatty acids (PUFAs) into the diet has been driven by the extensive literature indicating that these dietary PUFAs promote health and prevent disease [1–6]. Diets rich in PUFAs have been associated with reduced food intake, increased energy expenditure, lower body weight and fat mass, or a combination of all in rats, mice, and humans [7–11]. Additionally, there are a few acute meal challenge studies that show greater satiety with PUFAs than with monounsaturated fatty acid (MUFA), saturated fatty acid (SFA), or both [10–12]; however, research on subjective and physiological hunger and satiety responses to longer-term consumption of a PUFA-rich diet is lacking.

This work was supported by the California Walnut Commission. The funding source had no involvement in the study design; collection, analysis, or interpretation of data; the writing of the report; or the decision to submit the article for publication. CMP and JAC designed the research, raised the grants, and coordinated the complete project. JLS conducted the laboratory research. All authors performed the statistical analyses and wrote and critically reviewed the manuscript. The authors have approved the final version of the manuscript. The authors have no conflicts of interest to declare.

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http://dx.doi.org/10.1016/j.nut.2017.03.008
0899-9007/

Both short- and long-term appetite hormone signals are commonly studied after nutrient ingestion. Ghrelin, a hormone secreted by the stomach, is proposed to have appetite-stimulating effects. Plasma levels of ghrelin are elevated in fasted states to initiate feeding and to decrease after nutrient ingestion [13]. Conversely, peptide YY (PYY) is secreted by the small intestine and colon in response to nutrient ingestion and is purported to have appetite-suppressing effects [14,15]. Although PYY and ghrelin are thought of as short-term signals, insulin and leptin have both short- and long-term effects on energy homeostasis. Pancreas β cells secrete insulin, which functions to inhibit food intake [16,17]. Similarly, leptin acts as a satiety hormone and is secreted primarily by adipose tissue as well as in smaller amounts from the gastrointestinal tract [18,19]. Dietary manipulations that suppress ghrelin levels and increase plasma satiety hormone levels may offer pragmatic approaches for reducing energy intake. Although there have been a few studies that have examined acute physiological responses to high-fat (HF) meals or diets rich in different types of FAs [9,10,20,21], research on chronic consumption of a diet rich in a particular type of dietary FA is lacking. Of the previous acute studies, some have shown that PUFAs elicit the strongest postprandial PYY response [9–11]. Thus, initial acute studies show the potential for chronic appetite hormone differences based on FA composition of the diet. The purpose of this study was to determine the subjective and physiological appetite responses to two HF meals (breakfast and lunch) before and after a 7-d PUFA-rich diet or a control diet. We hypothesized lower fasting plasma ghrelin concentrations and higher fasting PYY concentrations would be observed after the 7-d PUFA-rich diet. We further hypothesized that consuming the PUFA-rich diet for 7 d would elicit a greater postprandial satiety response (greater ghrelin suppression and higher PYY, leptin, and insulin levels) to two HF meals versus the control diet. Finally, we hypothesized that visual analog scale (VAS) scores for hunger and fullness would correlate to plasma hormone levels.

Materials and methods

Study design

This 7-d outpatient feeding study was a randomized, single-blinded, placebo-controlled, parallel trial that was designed to test the subjective and physiological responses to two HF meals before and after a 7-d diet. This study was registered at clinicaltrials.gov. The study protocol consisted of a screening visit, a 3-d lead-in diet, a prediet visit, a 7-d feeding protocol (either a PUFA-rich or a control diet), and a postdiet visit (Table 1). For all testing procedures, participants reported to the Human Nutrition Lab (HNL) after an overnight fast (10–15 h) and without performing vigorous exercise for ≥12 h. The Institutional Review Board approved the study and procedures followed were in accordance with the Helsinki Declaration of 1975 as revised in 1983. Written, informed consent was obtained before beginning study procedures, and the privacy rights of human participants were always observed.

Participants

Thirty-two participants were randomly assigned to either the PUFA-rich diet (n = 16) or the control diet (n = 16). However, six participants either dropped out of the study or were excluded from further participation due to poor compliance to the diet during the study (all in the control group). Thus, 26 (n = 13 men and n = 13 women) healthy weight (body mass index [BMI] 18–24.9 kg/m^2), sedentary (perform <3 h/wk of structured exercise) adults between the ages of 18 and 35 y completed the study in its entirety and were included in final analyses. Exclusion criteria were history of chronic, metabolic, or endocrine disease; history of surgery that could affect digestion or hormone signaling; gastrointestinal disorders; and dyslipidemia (based on fasting blood sample drawn at screening visit). Individuals who were on a medically prescribed diet, took medications, supplements, or both; experienced body weight changes (3 mo before testing); and used tobacco also were excluded. Women who were pregnant, planning on becoming pregnant, or lactating were excluded.

Protocol

Screening visit and 3-d lead-in diet

At the screening visit, height, weight, 5 mL fasting blood draw (for a blood lipid panel) and resting metabolic rate (RMR) were obtained. The 5 mL of blood was collected into vaccutainers and immediately centrifuged at 3000*g* for 15 min at 4°C for lipid panel analyses (UniCel DxC 800 Synchron Clinical Systems, Beckman Coulter, Inc. Brea, California, USA). RMR (kcal/d) was measured for 30 min with a metabolic cart (TrueOne 2400, Parvo Medics, Sandy, Utah, USA). Thirty minutes of respiratory gases were collected, but only the final 20 min of data was used to calculate RMR using the full Weir equation [22]. Estimated total daily energy needs were calculated as participant's RMR × 1.65 (1.65 was used to represent an average US physical activity factor) and was used to calculate total daily energy needs for the 3-d lead-in diet, 7-d PUFA-rich diet, 7-d control diet, and the HF meals. The diet (kcal/d) was meant to keep participants in energy balance throughout the duration of the study. Once participants qualified for the study, they were randomized into one of the two treatment conditions: PUFA-rich or control diet. For allocation of participants, research personnel used a computer-generated list of random numbers to allocate participants to either the PUFA-rich or control diet. Participants were blinded as to which diet they were receiving.

After completion of the screening visit, participants were scheduled for the prediet visit. For 3 d before the prediet visit, participants were provided with a lead-in diet that was representative of the average US diet (Table 2). The lead-in diet provided ~29%, 31%, and 40% of energy at breakfast, lunch, dinner and snacks, respectively. However, participants could consume meals and snacks in any order they chose (except for breakfast, which was consumed in the HNL each morning), as long as they ate all the food that was provided each day. Finally, no additional foods or caloric beverages were permitted. Participants kept a food and physical activity log to help ensure compliance.

Prediet visit

Following a 3-d lead-in diet, participants completed the prediet visit (~9 h). For women, the prediet visit occurred during the follicular phase of the menstrual cycle (days 1 or 2). Height, body weight, body composition, and waist–hip circumference were measured. Body composition was measured using air displacement plethysmography (BodPod, Cosmed USA, Inc. Concord, California, USA). Next, an intravenous catheter was placed in the antecubital vein and a 15-mL fasting/baseline (t = 0) blood sample was drawn into chilled EDTA vaccutainers (Greiner Vacuette, Monroe, North Carolina, USA) and immediately centrifuged at 3000*g* for 15 min at 4°C. The line was kept patent with saline. Participants then completed a validated VAS [23]. Next, participants drank an HF liquid meal at 0800 within 5 min. Each liquid meal provided 35% of total daily energy needs. The macronutrient breakdown of the meals was 70% fat, 25%

Table 1
Timeline of study visits and measurements taken at each visit

	Screening visit	Lead-in diet	Prediet visit	7-d diet	Postdiet visit
Time	1 h	30 min	9 h	30 min/d	9 h
Protocol	Anthropometric measurements Fasting blood draw (screen for dyslipidemia) Indirect calorimetry	Provided all food for 3 d	Anthropometric measurements Fasting blood draw Two SFA-rich HF meal challenges (0800 & 1200) Postprandial blood draws and VAS every 30 min for 4 h after each meal challenge	Eat breakfast at HNL Provided food for entire day	Anthropometric measurements Fasting blood draw Two SFA-rich HF meal challenges (0800 & 1200) Postprandial blood draws and VAS every 30 min for 4 h after each meal challenge

HF, high-fat; HNL, Human Nutrition Lab; PUFA, polyunsaturated fatty acid; SFA, saturated fatty acid; VAS, visual analog scale