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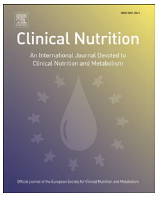

Original article

Higher visceral adiposity is associated with an enhanced early thermogenic response to carbohydrate-rich food

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SUMMARY

Background: Studies examining the dynamics of the thermic effect of feeding (TEF) of specific food items and the relationship of TEF to visceral adiposity are limited.
Methods: We measured resting energy expenditure (REE) and early-TEF (40-min postprandial, e-TEF) after 8-h fast by indirect calorimetry in 40 obese men, and imaged abdominal fat tissues by magnetic resonance imaging. Each participant was examined on two occasions, 3-weeks apart. At each examination we measured fasting REE and then postprandial REE following the isocaloric [~380 kcal] consumption of either 56 gr walnuts [(8% carbohydrates; 84% fat, of which 72% polyunsaturated fat)], or 5-slices (150gr) of whole-grain bread (48% carbohydrates; 32% fat). e-TEF was calculated as the area under the curve between the fasting and postprandial tests.
Results: Participants had a mean age of 45 ± 8 years, body-mass-index (BMI) = 31.1 ± 3.8 kg/m^2, total abdominal fat area = 901.4 ± 240 cm^2, visceral fat area (VAT) = 260 ± 102.9 cm^2, fasting REE = 1854 ± 205 kcal, REE/kg = 19.39 ± 1.73 kcal/kg, and respiratory quotient (RQ, $CO_{2\ \text{eliminated}}/O_{2\ \text{consumed}}$) = 0.82 ± 0.04. Individuals who exhibited increased e-TEF (top ΔAUC median) to bread had higher VAT (299 cm^2 vs. 223 cm^2; $p = 0.024$) and higher BMI (32.4 kg/m^2 vs. 30.0 kg/m^2; $p = 0.013$), compared to their peers with the lower e-TEF response (ΔAUC below median). As expected, postprandial e-TEF was higher after whole-grain bread consumption [ΔAUC = +14 kcal/40min] compared to walnuts [ΔAUC = −2 kcal/40 min; $p < 0.001$].
Conclusions: Higher early thermic effect of high-carbohydrate food, likely reflecting digestion, early absorption and/or sympathetic tone (rather than metabolic utilization (oxidation)), associates with visceral adiposity. Future studies are required to determine if this association represents an added causality between early carbohydrate processing and visceral fat accumulation.

1. Background & aims

Obesity is related to a chronic imbalance between total energy expenditure (TEE) and energy intake [1]. The major components of TEE are resting energy expenditure (REE; ~60–75% of TEE), thermic effect of feeding (TEF; ~10–15% of TEE), and energy cost of physical activity (~10–30% of TEE) [2].

TEF is the increase in metabolic rate above the resting levels attributed to digestion, absorption, and ultimately storage or utilization (oxidation) of ingested nutrients [2,3], and is regulated by

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Abbreviations: total energy expenditure, (TEE); early thermic effect of feeding, (e-TEF); monounsaturated fatty acids, (MUFAs); polyunsaturated, (PUFAs); visceral fat area, (VAT); resting energy expenditure, (REE); magnetic resonance imaging, (MRI); area under the curve, (AUC); body-mass-index, (BMI).

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the sympathetic nervous system [4]. The typical TEF pattern peaks 30–240 min after food consumption and then gradually returns to baseline REE, and may vary among individuals [5–7]. The TEF of isolated nutrients is the highest for protein (20–30% of the calories), followed by carbohydrates (5–10% of the calories), and fat (0–3% of the calories) [8].

Although early-TEF (e-TEF) may represent a relatively small portion of total TEE, it could play a role in the progression and maintenance of obesity in the long term [9]. Yet, studies evaluating the differences in TEF between lean and obese people have provided inconsistent results, with some studies showing reduced TEF in obesity [9–11] whereas others found no difference [12–14]. Moreover, the few studies examining the association of visceral adipose tissue with TEF are inconsistent [15,16]. Part of this inconsistency may be related to the different contributors to TEF and alterations in their inter-individual activation in response to food. Thus, in this study we evaluated e-TEF in response to two caloric-equivalent food items with distinct dietary composition. We reasoned that the early phases of TEF (i.e., before measurable changes in RQ) reflect thermogenesis attributed mainly to the digestion, early absorption, and early sympathetic flow, rather than to metabolic utilization (oxidation) of the food. We assessed whether this thermogenic response associates with fat distribution.

2. Methods

2.1. Study population

As part of the baseline measurements of the CENTRAL randomized controlled trial (ClinicalTrials.gov Identifier: NCT01530724) that assesses the effect of diet plus physical activity on abdominal fat distribution, we performed a sub-study among 40 men. Patients were eligible for this specific study if they were non-smokers, not taking medications affecting metabolic rate (e.g., beta blockers), and had no weight changes >2 kg in the previous 6 months. Additional inclusion criteria of the CENTRAL trial were: waist circumference $\geq$102 cm or TG > 150 mg/dL and high-density lipoprotein cholesterol below 40 mg/dL for men and below 50 mg/dL for women. Exclusion criteria were having nut allergy, serum creatinine $\geq$2 mg/dL, disturbed liver function ($\geq$3-fold level of ALT and AST enzymes), and active cancer. The study protocol was approved by the Soroka University Medical Center Medical Ethics Board and Helsinki Committee. All participants provided written informed consent and received no financial compensation or gifts.

2.2. Study procedure

We measured fasting and 40-min postprandial resting energy expenditure (REE), which reflects e-TEF, prior to utilization (oxidation) of the ingested food (as suggested by lack of change in Rq – see next).

Based on these measurements we calculated the e-TEF of the specific, provided food items. We performed the experiments in the Metabolic Unit of Ben-Gurion University, in the morning after an overnight fast of 8 h. Additionally, all subjects were asked to arrive by car or bus and were instructed to avoid any intense physical activity on the day of the test. After 10 min of rest and a “steady state” phase in energy expenditure was observed, we measured REE for 16 min. Immediately thereafter each subject received randomly one of two calorie-equivalent specific food items: A. Walnuts (56 gr): [total energy content 380 kcal (1590 kJ), 36 g of fat (of which 72% is polyunsaturated fat (PUFA)), 8 g of carbohydrates, 8 g of protein, and 4 g of dietary fiber]; B. Whole-grain bread (150 g, 5 slices) (total energy content 370 kcal (1548 kJ), 44.4 g of carbohydrates, 13.2 g of fat, 18.45 g of protein, and 16.65 g of dietary fiber). Subjects consumed the assigned food within 10 min and rested for 25 min, after which postprandial energy expenditure was measured continuously for 16 min. All participants were tested twice within 3 weeks – once for each food intervention.

2.3. Indirect calorimetry

REE was measured by indirect calorimetry (QUARK REE by COSMED, Rome, Italy) in which the quantity of oxygen consumed and carbon dioxide produced are measured and converted into kcal/kJ using the Weir equation [17]. Turbine calibration was performed every day and gas calibration before each test, as per the manufacturer's instructions. During the measurement, the subjects were awake in a supine position, in a quiet room with stable temperature (22–24 °C), with their head covered with a ventilated canopy. They were allowed to watch relaxing channels on TV in order to avoid falling asleep and extreme movements. Each measurement lasted for 20 min. The first 4 min (adaptation phase) were excluded and the mean REE of the subsequent 16 min was defined as the REE.

2.4. Anthropometric measurements

Height, weight, and waist circumference (WC) were measured just before the calorimetry measurement. Height was measured to the nearest millimeter using a standard wall-mounted stadiometer. Body weight was measured without shoes to the nearest 0.1 kg. WC was measured half-way between the last rib and the iliac crest to the nearest millimeter using a 150 cm anthropometric measuring tape. All measurements were performed twice on both occasions, and the mean values were used for analyses.

2.5. Magnetic resonance imaging (MRI) analysis

Abdominal subcutaneous and visceral fat areas were imaged by a 3 T MRI machine (Intera, Philips Medical Systems, Best, the Netherlands) using a body coil. Fat in the different sections was calculated from the MRI scans using a MATLAB-based program [18]. We calculated fat distribution using the area of the slice in the L5-L4 inter-vertebral space. Quantification of the fat mass regions included the area of each fat type and the proportion (percentage) of the total area of all fat types.

2.6. Statistical analysis

We calculated means and standard deviations for continuous variables to characterize the entire study population across tertiles of total abdominal adipose tissue (TAAT). The e-TEF was calculated as postprandial minus fasting REE. The incremental change in energy expenditure from baseline to the end of measurement was calculated as the area under the curve (AUC) of the mean REE per minute of each time point [19]. The e-TEF was expressed in absolute values (kcal/40 min). Mann–Whitney test was used to compared adiposity parameters between the “greater e-TEF responders” group (top median of the ΔAUC), who mostly increased their postprandial e-TEF, and the “lesser e-TEF responders” group (bottom median of ΔAUC). The Wilcoxon paired test was used to compare the differences in e-TEF between the two food items. We used SPSS 20 for the statistical analyses.

3. Results

Baseline characteristics of the study participants across tertiles of total abdominal adipose tissue (TAAT) are summarized in Table 1. Mean age was 45.2 ± 8.0 years and BMI range was 23.61–40.96 kg/