



## Research report

Eating-related behaviors and appetite during energy imbalance in obese-prone and obese-resistant individuals<sup>☆</sup>

Elizabeth A. Thomas<sup>a,b,\*</sup>, Jaime L. Bechtell<sup>a,b</sup>, Brian E. Vestal<sup>d</sup>, Susan L. Johnson<sup>c</sup>, Daniel H. Bessesen<sup>a,b</sup>, Jason R. Tregellas<sup>e,f</sup>, Marc-Andre Cornier<sup>a,b</sup>

<sup>a</sup> Division of Endocrinology, Metabolism and Diabetes, Department of Medicine, University of Colorado School of Medicine, Anschutz Medical Campus, Aurora, CO 80045, USA

<sup>b</sup> Anschutz Health and Wellness Center, University of Colorado Anschutz Medical Campus, Aurora, CO 80045, USA

<sup>c</sup> Division of Nutrition, Department of Pediatrics, University of Colorado School of Medicine, Anschutz Medical Campus, Aurora, CO 80045, USA

<sup>d</sup> Colorado Biostatistics Consortium, Research Consulting Lab, Biostatistics and Informatics, Colorado School of Public Health, University of Colorado Anschutz Medical Campus, Aurora, CO 80045, USA

<sup>e</sup> Department of Psychiatry, University of Colorado School of Medicine, Anschutz Medical Campus, Aurora, CO 80045, USA

<sup>f</sup> Research Service, VA Medical Center, Denver, CO 80220, USA

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## ABSTRACT

While the majority of Americans are now overweight, some individuals maintain their weight with minimal effort. This study investigated behavioral differences between 58 individuals recruited as either obese-resistant (OR) or obese-prone (OP) based on self-identification, BMI, and personal/family weight history. Subjects were studied during Eucaloric (EU), Overfed (OF), and Underfed (UF) phases which included a run-in diet, 1 day intervention diet, and a study day. At baseline, subjects completed the Three Factor Eating Questionnaire (TFEQ) and Power of Food Scale (PFS). On the study day, ratings of appetite, food appeal and desire, and food cravings were performed in response to a breakfast shake. OF resulted in reduced hunger and food desire while UF resulted in increased hunger and food appeal and desire. While hunger did not differ between groups, OP had higher scores for TFEQ measures (hunger, restraint and disinhibition), higher “hedonic hunger” as measured by the PFS, and greater food cravings and ratings of food appeal and desire. These results suggest that subjective hunger and desire for food change significantly after only one day of over- or underfeeding. Additionally, we found several behavioral differences between groups that are likely to promote weight gain over time in the OP.

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## Introduction

Despite efforts to promote healthy eating and physical activity behaviors in Americans, the prevalence of obesity and related metabolic disorders such as diabetes continue to increase. As of 2010, a majority of Americans were either overweight or obese (69%) leaving only a minority with a “normal” body mass index (BMI) (Flegal, Carroll, Kit, & Ogden, 2012). One of the most dramatic changes in the environment over the last 40 years has been the broad availability of relatively inexpensive, highly palatable foods leading to excessive energy intake. Most people in the United States experi-

ence at least brief periods of positive energy balance produced by the over-consumption of highly palatable food combined with periods of low levels of physical activity. Evidence that brief periods of positive energy balance are clinically relevant comes from a study of “holiday weight gain” (Yanovski et al., 2000). In this study many individuals maintained their body weight over the holiday season, while others (largely the obese) tended to have large gains over a short period of time. Perhaps more importantly, weight gained over this brief period of time tended to remain. In addition, it has been shown that US adults consume significantly more energy over the weekend (Friday through Sunday) than they do during weekdays, again implying brief periods of over-nutrition (Haines, Hama, Guilkey, & Popkin, 2003).

While the rise in the prevalence of obesity is concerning from a health care perspective, it also begins to refocus attention on those who do not gain weight. Clearly some individuals maintain a healthy weight in the face of an environment that promotes weight gain in a majority of Americans. It is of great interest to determine what factors prevent these “obese resistant” individuals from gaining weight.

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\* Corresponding author.

E-mail address: [Elizabeth.Thomas@ucdenver.edu](mailto:Elizabeth.Thomas@ucdenver.edu) (E.A. Thomas).

There is a great deal of prior work investigating behavioral differences between obese and normal weight individuals. It can be hypothesized that obese individuals might report food cravings that differ from normal weight individuals in quality or quantity. In fact, in developing the Food Craving Inventory as a tool to assess cravings, White et al. found associations between food cravings and BMI (White, Whisenhunt, Williamson, Greenway, & Netemeyer, 2002). Additionally, in the Diabetes Prevention Program, frequency of food cravings was found to correlate positively with baseline BMI (Delahanty et al., 2002). Eating behaviors have also been shown to have important relationships with the development of obesity. Three recognized eating behavior constructs are “disinhibition,” “restraint,” and “hunger,” which are commonly assessed using the Three Factor Eating Questionnaire (TFEQ) developed by Stunkard and Messick (Stunkard & Messick, 1985). Disinhibition was defined originally as “disinhibition of cognitive control of eating,” and has since been described as the tendency to overeat in response to different stimuli including emotional distress or situations in which an array of palatable foods is available (Lowe & Maycock, 1988; Stunkard & Messick, 1985). Disinhibition has been shown to be strongly associated with weight gain over time and obesity in adult life (Drapeau et al., 2003; Hays et al., 2002; Hays & Roberts, 2008). Given the increased prevalence of highly palatable food in the environment and its likely role in the increased rates of obesity, the Power of Food Scale has been developed to assess the psychological impact of living in food-abundant environments, as reflected in feelings of being controlled by food, independent of food consumption itself (Lowe et al., 2009). Severely obese individuals have been shown to achieve higher Power of Food scores as compared with non-obese control subjects, interpreted as increased “hedonic hunger,” or drive to eat palatable foods in the absence of energy need (Schultes, Ernst, Wilms, Thurnheer, & Hallschmid, 2010). While these differences have been observed in obese as compared to normal weight individuals, they have not been investigated in normal weight individuals who vary in their propensity to gain weight.

In order to assess these potential differences, we compared individuals who were resistant to weight gain (obese-resistant – OR) to other non-obese individuals who were likely to be at risk for weight gain (obese-prone – OP). Previously we found that thin, OR individuals quickly sensed changes in energy balance (short-term overfeeding) with significant decreases in subjective measures of hunger and increases in measures of satiety. In addition, these individuals appeared to also adapt by consuming less energy in the days following a period of overfeeding (Cornier, Grunwald, Johnson, & Bessesen, 2004). It is unclear whether differences in the ability to adapt energy intake to current energy status is related to differences in hormones and metabolites, differences in the nutrient sensing by the brain, or underlying behavioral differences between OP and OR individuals.

This study was designed to investigate behavioral qualities in OP and OR individuals and to assess the effects of short-term over- and under-feeding on appetitive response, food cravings, and ratings of food images. We hypothesized that the OP would exhibit baseline behavioral differences as compared to the OR, as well as differences in response to energy imbalance (over- and underfeeding) that would predispose them to weight gain over time.

## Methods

### Ethics statement

This study was conducted according to the principles expressed in the Declaration of Helsinki. The study was approved by the Colorado Multiple Institutional Review Board. All patients provided

written informed consent for the collection of samples and subsequent analysis.

### Subjects

Subjects included healthy men and women, ages 25–35 years, without eating disorders or depression, who were empirically classified as either obese-resistant (OR) or obese-prone (OP) as described previously (Table 1) (Schmidt, Harmon, Sharp, Kealey, & Bessesen, 2012; Schmidt, Kealey, Horton, Vonkaenel, & Bessesen, 2012; Smucny et al., 2012). Subjects who were OR had a BMI of 17–25 kg/m<sup>2</sup>, self-reported no first degree relatives with a BMI > 30 kg/m<sup>2</sup>, and identified themselves as constitutionally thin based on their perception of difficulty gaining weight despite expending little effort to maintain their current weight. These individuals responded to advertisements asking “Have you always been thin?” and reported no history of ever being overweight. Individuals who were OP, in contrast, responded to the advertisement “Do you struggle with your weight?” They had a BMI of 20–30 kg/m<sup>2</sup>, had at least one first degree relative with a BMI > 30 kg/m<sup>2</sup>, reported having to put effort into not gaining weight, reported previous attempts to lose weight, but were not actively attempting to lose weight. All subjects were weight stable for at least 3 months before being studied and reported that they did not engage in planned physical activity more than 3 h per week. OR and OP subjects were matched for sex, age ( $\pm 2$  years), and ethnicity/race.

### Study design and measurements

Subjects first underwent baseline assessments, including completion of the TFEQ and the Power of Food Scale (Lowe et al., 2009; Stunkard & Messick, 1985). They also underwent body composition measurement (lean body mass, fat mass, and fat-free mass) by dual-energy X-ray absorptiometry (DEXA) (DPX whole-body scanner, Lunar Radiation Corp., Madison, WI). Each subject participated in three study phases in a randomized counterbalanced manner, with each phase consisting of a 3 day baseline eucaloric run-in diet period (50% carbohydrate, 30% fat, and 20% protein), followed by an intervention diet on day 4, then a study day on day 5. The three study phases consisted of one of the following on day 4: Eucaloric (EU) diet, Overfeeding (OF) by 40% above estimated energy needs, or Underfeeding (UF) by 40% of baseline caloric intake. During all three study periods, the diets were made up of the same macronutrient composition (50% carbohydrate, 30% fat, and 20% protein). Estimates of daily energy needs were made using lean body mass (as determined by DEXA) in the following equation: Resting Metabolic Rate (RMR) = (fat free mass · 23.9) + 372. The estimates were confirmed using RMR as

**Table 1**  
Baseline characteristics.

	OR	OP
Total n (male/female)	29 (15/14)	29 (14/15)
Age (years)	30.7 ± 3.4	30.4 ± 3.9
BMI (kg/m <sup>2</sup> )	20.9 ± 1.9	26.1 ± 2.8 <sup>a</sup>
Lean body mass (kg)	48.5 ± 10.3	53.4 ± 10.4
Fat mass (kg)	10.7 ± 3.6	22.7 ± 8.0 <sup>a</sup>
Percent body fat	18.8 ± 4.6	28.7 ± 8.0 <sup>a</sup>
Hunger	4.5 ± 2.4	6.3 ± 2.9 <sup>b</sup>
Restraint	4.6 ± 3.0	9.4 ± 4.4 <sup>a</sup>
Disinhibition	3.1 ± 2.2	7.7 ± 3.5 <sup>a</sup>
Power of Foods Scale	39.2 ± 10.2	49.5 ± 14.1 <sup>b</sup>

Mean ± standard deviation for obese-resistant (OR) and obese-prone (OP).

<sup>a</sup>  $p < 0.001$ .

<sup>b</sup>  $p < 0.05$ .

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