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APPETITE SENSATIONS AND SATIETY QUOTIENT: PREDICTORS OF ENERGY INTAKE AND WEIGHT LOSS

Vicky Drapeau[1], Neil King[2], Marion Hetherington[3], Eric Doucet[4], John Blundell[2] and Angelo Tremblay[1].

[1]Division of Kinesiology, Laval University and Laval Hospital Research Center, Québec, Canada

[2]Institute of Psychological Sciences, Leeds University, UK

[3]Department of Psychology, Glasgow Caledonian University, UK

[4]School of Human Kinetics, University of Ottawa, Ontario, Canada

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Correspondence to:

Angelo Tremblay, Ph.D.
Division of Kinesiology, Laval University,
Ste-Foy, Québec, Canada, G1K 7P4
Phone: (418) 656-3842, Fax:(418) 656-2441
email: angelo.tremblay@kin.msp.ulaval.ca

ABSTRACT

PURPOSE: The aim of this study was to further evaluate the validity and clinical meaningfulness of appetite sensations to predict overall energy intake as well as body weight loss. METHODS: Men (n=176) and women (n=139) involved in six weight loss studies were selected to participate in this study. Visual analogue scales were used to measure appetite sensations before and after a fixed test meal. Fasting appetite sensations, 1-h post-prandial area under the curve (AUC) and the satiety quotient (SQ) were used as predictors of energy intake and body weight loss. Two separate measures of energy intake were used: a buffet style *ad libitum* test lunch and a three-day self-report dietary record. RESULTS: One-hour post-prandial AUC for all appetite sensations represented the strongest predictors of *ad libitum* test lunch energy intake **($p \leq 0.001$). These associations were more consistent and pronounced for women than men. Only SQ for fullness was associated with *ad libitum* test lunch energy intake in women.** Similar but weaker relationships were found between appetite sensations and the 3-day self reported energy intake. Weight loss was associated with changes in appetite sensations ($p \leq 0.01$) and the best predictors of body weight loss were fasting desire to eat; hunger; and PFC ($p \leq 0.01$). CONCLUSIONS: These results demonstrate that appetite sensations are relatively useful predictors of spontaneous energy intake, free-living total energy intake and body weight loss. They also confirm that SQ for fullness predicts energy intake, at least in women.

Keywords: appetite sensations, satiety quotient, energy intake, body weight loss.

INTRODUCTION

Obesity is the result of long term positive energy balance but its long term treatment remains illusive. The multifactorial nature of obesity **could possibly explain** the inter-individual variability in weight loss observed in subjects to the same treatment intervention. The assessment of factors implicated in obesity is a real clinical concern to improve obesity treatment. For example, the assessment of energy intake through dietary records represents an important issue in the characterisation of factors implicated in obesity but its validity is frequently compromised by underreporting (Pannemans, 1993; Johnson, 1994; Buhl, 1995; Schoeller, 1995; Westerterp, 2002).

Considering the apparent lack of success in the long term treatment of obesity, there is a need to investigate more reliable markers of overall energy intake as well as predictors of body weight loss. Appetite sensations are a reliable and valid method of measuring subjective states of motivation to eat before and in response to meals (Raben, 1995; Flint, 2000). In controlled laboratory conditions, subjective appetite sensations have been shown to be associated with measured energy intake (Parker, 2004) but not with reported energy intake in a free living context (Mattes, 1990). Recently, we demonstrated that appetite sensations measured in response to a standardized breakfast test meal represented markers of overall intake (Drapeau, 2005). In this study, 1-hour post meal **area under the curve (AUC, i.e. appetite sensation responses to a test meal)** and the **satiety quotient (SQ, i.e. individual satiety signal capacity in response to a test meal)** were identified as predictors of energy intake. Moreover, fullness represented the appetite sensation which was the strongest predictor of long term total energy intake and relative energy intake. However, **our earlier study** included a relatively small number of participants (men n=28 and women n=23) with different weight status (normal weight, obese and reduced

obese) and was only cross-sectional. **Our previous findings** prompted us to validate these findings in a larger cohort of obese individuals tested before and after weight loss. Thus, the results of six weight loss studies were analyzed retrospectively to 1) confirm the extent to which appetite sensation responses to a standardized meal test (e.g., 1-h post meal AUC and SQ) are potential markers of individual energy intake and to 2) investigate to what extent these variables measured upon initiation of a weight loss program predict individual body weight loss.

RESEARCH METHODS AND PROCEDURES

Subjects

The subjects who participated in this study were involved in a series of obesity treatment studies at Laval University. They were recruited through advertisements placed on the University campus or through radio advertisements. Eligibility of the participants was determined by a telephone interview. Inclusion criteria were: age between 20-50 years, obese (BMI between 30.0-35.0 kg/m^2), apparent good health, no medication, sedentary to moderately active (low intensity physical activities such as brisk walking, 3 times/week or less, no more than 30 min/session), consumption of less than five cups of coffee/day, consumption of less than two alcohol drinks/day or less than 9 alcohol drinks/week, a body weight variation less than ±4 kg for at least 2 months prior to the study, and premenopausal status for women. In the present study, we selected subjects who completed baseline testing sessions (i.e. standardized meal test, buffet type meal test and/or 3-day dietary records). Based on these criteria, a total of 176 men and 139 women were selected to participate in this study. Subjects were blind to the study objectives but were informed about the original nature of the study, i.e. weight loss. Written informed consent

was provided by each participant and all studies were approved by the Laval University Ethics Committee.

As mentioned above, subjects were selected from different weight loss studies (Table 1). The weight loss interventions included either a nutritional and physical activity intervention, or a drug treatment. The dietary intervention was based on an energy restriction of between 500-700 kcal/day. The weight loss intervention period varied between 4 to 52 weeks. Similar mean body weight loss was observed for men and women (-4.8 ±0.4 kg vs -4.5 ±0.5 kg, respectively). Participants were evaluated before (baseline data) and after the weight loss program (longitudinal data).

Appetite sensation and anthropometric measurements

The first test consisted of the fixed breakfast test meal with one hour post meal appetite measurements. **This test, which is routinely conducted in all weight loss studies performed in our laboratory, aimed to investigate the impact of a certain amount of calories on acute appetite sensations. It is also designed to be exported in a clinical context where time represents an important issue. To perform this test,** subjects were asked to arrive at the laboratory in the morning after an overnight fast (12-hours) and to refrain from alcohol consumption and intense physical activity **for the** 24 hours before the testing session. The standardized breakfast was served between 7h30 and 9h30 in order to replicate the usual breakfast time of each participant. The energy content of the test meal was 733 kcal (3066 kJ) and 599 kcal (2504 kJ) for men and women, respectively (Appendix 1). All participants were instructed **to consume all the food in no more than 30 minutes**. Before, immediately after, and every 10 min for a one-hour period after the standardized breakfast test, subjects were asked to

record their appetite sensations for "desire to eat", "hunger", "fullness" and "prospective food consumption " (PFC) on visual analogue scales (VAS) adapted from Hill and Blundell (Hill, 1986). Subjects were asked to indicate, on a scale from 0 to 150 mm, how they felt at the moment they completed these questions: How strong is your desire to eat? (very weak-very strong); How hungry do you feel? (not hungry at all- as hungry as I ever felt); How full do you feel? (not full at all- very full); How much food do you think you could eat? (nothing at all- a large amount). Subjects were also asked to rate the palatability of the breakfast using VAS.

The baseline appetite ratings immediately before the fixed breakfast test meal were referred to as the fasting appetite sensations. The appetite sensation responses to the standardized test meal were evaluated by calculating the **one-hour post meal AUC** (1-h post-prandial AUC) with the trapezoid method (Doucet, 2003). The satiety signal capacity or efficiency was assessed with the SQ concept adapted from Green et al. (Green, 1997). Thus, for each **appetite sensation (AS),** the SQ was calculated with this equation:

$$[SQ]\ (\text{mm/kcal}) = \frac{(\text{fasting AS} - \text{mean 60 min post meal AS})}{\text{energy content of the test meal (kcal)}} \times 100$$

Because energy content of the fixed meal was different between men and women, the theoretically possible range of SQ values was between –20 to 20 for men and –25 to 25 for women; a higher SQ representing greater satiety and a lower SQ lower satiety. SQ has been shown to be associated with energy intake (Drapeau, 2005) and is considered a more valid indicator of satiety than the 1-h post prandial AUC because it takes into account the pre-meal appetite sensations **and considers the caloric content of the meal**.

After the fixed breakfast test meal, body weight, height (bathing suit, without shoes), waist circumference (Lohman, 1988) and percent body fat were assessed for each subject. Percent body fat was determined by the underwater weighing technique. The closed circuit helium dilution method (Meneely, 1949) was used to assess the residual lung volume. The Siri formula (Siri, 1956) was used to estimate body fat from body density.

Ad libitum energy intake

After the anthropometric measurements subjects relaxed in a quiet room and were instructed not to eat or drink anything, except water, until lunch time. At about 12:00, each subject was provided with an *ad libitum* buffet-style test meal to measure *ad libitum* energy intake. The buffet type meal was composed of variety of foods which varied in macronutrient composition. Subjects had already completed a food preference questionnaire to ensure that they liked the buffet foods using a scale from 0 to 5 (0 -don't like at all to 5- like very much). If subjects rated more than 50% of the foods lower than 3, they did not participate in the study. The fixed breakfast and *ad libitum* test meals were provided in the laboratory and consumed under the same conditions i.e. alone, in a quiet place, without reading materials. All foods were weighed to the nearest 0.1g immediately before and after the test meals.

Self-report energy intake

Self-reported energy intake was assessed by a three-day dietary record (Tremblay, 1983) which was completed during two week days and one week-end day. All subjects received guidelines from a nutritionist on the procedures required to complete the dietary record and to measure food portions. The diary was reviewed by the study nutritionist during an interview with the subject. A computerized version of the Canadian Nutrient File (Health and Welfare Canada, 1991) or the

Food Processor software (Version 7.60, ESHA Research, Salem, Oregon, 2000) were used to calculate reported energy intake from the dietary records and *ad libitum* energy intake at the test lunch.

Statistical analysis

One-hundred and seventy six (176) men and 139 women were selected for the baseline statistical analysis and 142 men and 111 women were included in the longitudinal analysis (i.e. before and after weight loss). **Different sample sizes were selected for the baseline and longitudinal analyses mainly because of drop-outs and/or a missing test in the weight loss studies**. One way ANOVA was used to assess sex differences while a mixed model ANOVA was used to assess the effect of weight loss on all dependent variables. Partial correlations adjusting for initial body weight were performed to evaluate the associations between the appetite sensations (fasting state, 1-h post meal AUC and SQ) and the other dependent variables (*ad libitum* energy intake, reported energy intake and body weight loss) for all the groups and for men and women separately. **Baseline correlations were also adjusted for the covariate "study"**. **The Bonferroni correction was not used in this study for the following reasons: 1) appetite sensation variables highly covariate between each other (Perneger, 1998), and 2) there were a number of specifically hypothesised correlations between appetite sensation variables and energy intake variables (Stubbs, 2000). In this context, a general Bonferroni correction would be invalid since this does not allow adjustment for predicted relationships and the direction of relationships.** Significant differences were however considered significant at $p \leq 0.01$. All values are expressed as a mean ± SE. Analyses were performed using Jump Software 3.1.6.2 from SAS Institute Inc. (Cary, NC, USA).

RESULTS

Baseline data

Baseline characteristics of men (n = 176) and women (n = 139) are presented in Table 2. Men had a significantly higher body weight ($p \leq 0.0001$), BMI ($p \leq 0.01$), and lower percent body fat ($p \leq 0.0001$) than women. Appetite sensations measured before and after the fixed breakfast test meal revealed that men experienced a higher fasting PFC ($p \leq 0.01$) and 1-h post meal AUC for all appetite sensations ($p \leq 0.0001$), but lower satiety quotients ($p \leq 0.0001$) compared with women. There was no statistically significant difference in the ratings of palatability of the test meals between the men and women (mean VAS scores of 107 ±9 mm and 115 ±2 mm, respectively). Test meal and self-reported energy intakes were higher in men compared with women ($p < 0.0001$).

TABLE 2 ABOUT HERE

The relationships between appetite sensations and energy intake variables were evaluated for data pooled of men and women as well as for men and women separately (Table 3). In the fasting state, desire to eat, hunger and PFC predicted *ad libitum* energy intake ($0.01 \leq p \leq 0.0001$). One-hour post-prandial AUC for desire to eat, hunger, and PFC were positively correlated with *ad libitum* energy intake (**$0.01 \leq p \leq 0.0001$**) and 1-h post-prandial AUC for fullness was negatively correlated with *ad libitum* energy intake ($p \leq 0.0001$). In general, these relationships were stronger and more consistent in women than in men (Table 3). SQ for fullness was the SQ dimension for which there was a significant negative correlation with *ad libitum* energy intake ($p < 0.05$), at least in women ($p \leq 0.01$). **Similar relationships were**

found between appetite sensation variables (fasting state and 1-h post meal AUC) and self-reported energy intake (Table 4).

TABLES 3 AND 4 ABOUT HERE

Longitudinal data

Figures 1 to 3 display the appetite sensations before and after weight loss. After weight loss, there was a significant increase in fasting desire to eat ($p \leq 0.0001$), hunger ($p \leq 0.001$) and PFC ($p \leq 0.01$) in men, but not in women (Figure 1). One-hour post meal AUC in response to the fixed breakfast test meal was not changed after weight loss in both genders (Figure 2). Furthermore, there was an increase in the SQ for desire to eat ($p \leq 0.0001$), hunger ($p \leq 0.001$), and PFC ($p \leq 0.0001$) in men after weight loss, which was not apparent in women (Figure 3).

FIGURES 1, 2 AND 3 ABOUT HERE

Changes in fasting appetite sensation were also related with body weight loss. Accordingly, higher weight loss was associated with an increase in fasting desire to eat ($r = -0.20$, $p \leq 0.01$), and PFC ($r = -0.14$, $p \leq 0.01$). Changes in SQ for desire to eat was also related with changes in body weight ($r = -0.14$, $p \leq 0.01$). There was no interaction between men and women. Fasting state appetite sensations represented the best predictors of body weight loss. That is, the greater fasting desire to eat, hunger and PFC, the lower body weight loss in obese individuals with no interaction between men and women (desire to eat, $r = 0.22$; $p \leq 0.001$; hunger, $r = 0.20$; $p \leq 0.01$; and PFC $r = 0.22$; $p \leq 0.001$). Relationships were also found between 1-h post prandial AUC for hunger ($r = 0.17$, $p \leq 0.01$) and fullness ($r = -0.20$, $p \leq 0.01$) and changes in body

weight. No consistent relationship was found between the SQ variables and change in body weight (data not showed).

DISCUSSION

The main aim of this study was to further evaluate the clinical meaningfulness and validity of appetite sensations, measured before and after a test meal, as predictors of energy intake and body weight loss. Post-prandial appetite sensation responses (1-h post meal AUC) were the best predictors of spontaneous *ad libitum* test meal energy intake measured at lunch and self-reported energy intake assessed over three days. These relationships were stronger and more consistent for women than men, **more particularly for measured energy intake**. Furthermore, the SQ for fullness was also identified as the best predictor of *ad libitum* and self-reported energy intakes but this was significant only in women.

These results corroborate previous studies showing that appetite sensations represent relatively good predictors of acute measures of energy intake (Raben, 1995; Flint, 2000; Stubbs, 2000). The present results are also concordant with those obtained in a recent study (Drapeau, 2005). In this latter study, 1-h post meal AUC for fullness was the appetite sensation most strongly associated with measured energy intake and the SQ for fullness was the only SQ dimension negatively related with measured energy intake. Except for SQ for fullness in women, we did not find that 1-h post meal AUC for fullness was the strongest predictor of measured *ad libitum* energy intake. In fact, all 1-h post meal appetite sensations were associated with measured *ad libitum* energy intake as well as with reported energy intake. These results are also partly in accordance with those observed in another weight loss intervention in which there was no association between appetite ratings before weight loss and measured or reported energy intakes

(Doucet, 2003). However, measured energy intake was significantly associated with post-prandial AUC for fullness and PFC in men at the end of the weight loss program. Differences in the time intervals between the measurement of appetite sensations and energy intake could explain these inconsistent results. In the present study, *ad libitum* energy intake was measured shortly after the appetite sensation assessment (about 4 hours) whereas a 2-week period separated the measurement of these two variables in the previous study (Doucet, 2003). Moreover, different numbers of subjects, measures of energy intake, and testing environment could account for the differences. Nevertheless, it seems that the 1-h post meal AUC represents an appetite sensation indicator of acute and medium-term (up to 2 week) energy intake. This is supported by the association between appetite sensations in response to a test meal and both measured *ad libitum* and reported energy intakes. The relative agreement between subjective sensations and measured *ad libitum* or reported energy intake is an important aspect in the present study since it suggests that the predictability of appetite sensations can be transposed, to a certain extent, in a clinical context.

The results pertaining to the relationship between all post meal appetite sensation responses and/or SQ for fullness and energy intake (*ad libitum* and reported) suggested that these appetite sensation variables could be related with body weight changes. However, we found that fasting appetite sensations were the best predictor of body weight loss, i.e, higher fasting appetite sensations for desire to eat, hunger and PFC were associated with a lower body weight loss. We also observed that higher post meal AUC for desire to eat and lower post meal AUC for fullness were associated with lower body weight loss. Surprisingly, SQ for fullness was not related with changes in body weight. This finding is counterintuitive because a higher SQ for fullness (i.e. more satiating effect) was expected to be associated with greater body weight loss. This paradox

suggests that fasting appetite sensations operate differently to meal-induced (i.e. SQ) appetite responses. Indeed, the SQ and fasting appetite sensations are completely different measures – one is a pure biopsychological sensation (i.e. subjective state) and the other is a derivative of the interaction between the energy value of a meal and changes in subjective states. These unexpected results could have been influenced by nature of the weight loss protocol which included specific energy restriction and/or a drug treatment imposed on obese individuals, however there was no significant interaction between diet and drug interventions (data not **shown**). Nevertheless, it is possible that the weight loss intervention context could have influenced the capacity of obese subjects to eat in response to their hunger and satiety sensations.

In accordance with other studies (Doucet, 2000; Doucet, 2003), we also observed changes in fasting appetite sensations, 1-h post meal appetite sensations and SQ after weight loss. Accordingly, an increase in fasting desire to eat, hunger and PFC and an increase in SQ for desire to eat, hunger and PFC after weight loss was observed in men but not in women. Changes in fasting state appetite sensation and SQ for desire to eat after weight loss were also associated with body weight loss suggesting that **a** higher body weight loss was associated with higher increase in fasting appetite sensations and SQ for desire to eat. These results could seem paradoxical. However, we know that inducing weight loss increases hunger probably via changes in leptin and/or increase cortisol level (Doucet, 2000). The increase in SQ also observed after weight loss means a greater satiating effect of the test meal after weight loss, suggesting that the system is more sensitive to food-induced satiety signals**. Since weight loss also increases insulin sensitivity (Dengel, 2006),** we could expect that changes in insulin sensitivity would be related with changes in SQ. However, we did not find a relationship between changes in fasting insulin levels and changes in SQ in this study (data not **shown**). Nevertheless, it is not excluded

that other peptides or hormones could be implicated in this increased sensitivity of the satiety system signalling.

Even though we found relationships between appetite sensations and energy intake or body weight loss, it **could** be argued that the strength of these relationships **was** relatively small. **Accordingly, after adjustment for initial body weight, only 4-5% of the variability of weight loss could be predicted by the fasting appetite measures. The addition of other predictors such as age and/or fat free mass did not increase the predictive power of appetite sensations**. Many **other** factors such as restraint and disinhibition could have influenced the strength of our results. For example, it has been shown that restraint behaviour, which is higher in individuals seeking participation in weight loss interventions (Boschi, 2001), influence energy intake (Provencher, 2003) as well as SQ scores (Green, 1997). In our study, although we did not measure eating behaviors in all participants, we suspect that some behaviors such as restraint influenced measured and reported energy intake, especially in women. It is also important to consider that energy intake at a meal can also be influenced by other factors such as palatability, external factors, gender, body weight and genes (de Castro, 1993; Yeomans, 1996; Tuomisto, 1998; Jéquier, 1999). Different weight loss strategies used in intervention studies could also have influenced the strength of our results.

One objective of this study was to further evaluate the clinical meaningfulness and validity of appetite sensations in response to a test meal to predict individual spontaneous energy intake and body weight loss. In this regard, the use of a fixed breakfast test meal to assess different appetite sensations represented a simple, easy to administer, and inexpensive clinical test that could provide some information about individual overall energy intake as well as body weight

loss capacity. On the other hand, the standardized test meal could represent one limitation in this study since it does not consider differences in subject's normal meal size and/or body weight – although the fixed breakfast meal was tailored to gender. Nevertheless, the use of a fixed test meal has the advantage to decrease social bias that could be observed with an *ad libitum* test meal. Another possible limitation of this study concerned the three-day dietary record. We are aware that this method is exposed to underreporting (Pannemans, 1993; Johnson, 1994; Buhl, 1995; Schoeller, 1995; Westerterp, 2002). However, the use of the dietary record to assess free-living energy intake was supported by the fact that, in our previous study (Drapeau, 2005), a positive relationship was found between measured total energy intake and reported energy intake derived from a three-day dietary record, suggesting that underreporting under these conditions was minimal.

In conclusion, this study confirms previous findings showing that appetite sensation responses to a test meal could be relatively useful in a clinical context to predict acute and free-living energy intakes and intervention-induced body weight loss. In this regard, the 1-h post meal AUC for all appetite sensations as well as SQ for fullness represented the strongest and most consistent markers of *ad libitum* and reported energy intakes. However, when it comes to predicting body weight loss, fasting state appetite sensation for desire to eat, hunger and PFC represented the best markers. Other longitudinal studies should be performed to explore the relationship between appetite sensation responses to a test meal, body weight variations and changes in different satiety related peptides/hormones in a free-living context.

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Appendix 1 Composition of the breakfast test meal for men and women

Foods	Men Weight (g)	Energy kcal	(kJ)	Women Weight (g)	Energy kcal	(kJ)
White bread	100	261.2	(1092.3)	80	209.0	(874.0)
Butter	12	88.6	(370.5)	12	88.6	(370.5)
Peanut butter	16	102.5	(428.7)	16	102.5	(428.6)
Cheddar cheese	40	164.5	(687.9)	20	82.3	(344.2)
Orange juice	250	116.3	(486.4)	250	116.3	(486.4)
Total	418	733.1	(3065.8)	378	598.7	(2503.7)

RERERENCES

Boschi, V., D. Iorio, N. Margiotta, P. D'Orsi and C. Falconi (2001). The three-factor eating questionnaire in the evaluation of eating behaviour in subjects seeking participation in a dietotherapy programme. *Annals of Nutrition and Metabolism* 45: 72-7.

Buhl, K. M., D. Gallagher, K. Hoy, D. E. Mattews and S. B. Heymsfield (1995). Unexplained dysturbance of body weight regulation: diagnostic outcome assessed by doubly labelled water and body composition analyses in obese patients reporting low energy intakes. *American Journal of Dietetic Association* 95: 1393-1400.

de Castro, J. (1993). Independence of genetic influences on body size, daily intake, and meal patterns in humans. *Physiology and Behavior* 54: 633-639.

Dengel, D. R., A. S. Kelly, T. P. Olson, D. R. Kaiser, J. L. Dengel and A. J. Bank (2006). Effects of weight loss on insulin sensitivity and arterial stiffness in overweight adults. *Metabolism* 55: 907-11.

Doucet, E., P. Imbeault, S. St-Pierre, N. Almeras, P. Mauriege, D. Richard and A. Tremblay (2000). Appetite after weight loss by energy restriction and a low-fat diet-exercise follow-up. *International Journal of Obesity and Related Metabolic Disorders* 24: 906-914.

Doucet, E., S. Saint-Pierre, N. Almeras and A. Tremblay (2003). Relation between appetite ratings before and after a standard meal and estimates of daily energy intake in obese and reduced-obese individuals. *Appetite* 20: 137-43.

Drapeau, V., J. Blundell, F. Therrien, C. Lawton, D. Richard and A. Tremblay (2005). Appetite sensations as a marker of overall intake. *British Journal of Nutrition* 93: 273-280.

Flint, A., A. Raben, J. E. Blundell and A. Astrup (2000). Reproducibility, power and validity of visual analogue scales in assessment of appetite sensations in single test meal studies. *International Journal of Obesity* 24: 38-48.

Green, S. M., H. Delargy, D. Joanes and J. E. Blundell (1997). A Satiety Quotient: a formulation to assess the satiating effect of food. *Appetite* 29: 291-303.

Health and Welfare Canada (1991). The Canadian Nutrient File., Government of Canada.

Hill, A. J. and J. E. Blundell (1986). The effects of a high-protein or high-carbohydrate meal on subjective motivation to eat and food preferences. *Nutrition and Behavior* 3: 133-144.

Jéquier, E. and L. Tappy (1999). Regulation of body weight in humans. *Physiological Reviews* 79: 451-480.

Johnson, R. K., M. I. Goran and E. T. Poehlman (1994). Correlates of over- and underreporting of energy intake in healthy older men and women. *American Journal of Clinical Nutrition* 59: 1286-90.

Lohman, T. G., A. F. Roche and R. Martorell (1988). Anthropometric standardization reference manual. *Anthropometric standardization reference manual.* T. G. Lohman, A. F. Roche and R. Martorell. Champaign, Human kinetics books**:** 55-80.

Mattes, R. (1990). Hunger ratings are not a valid proxy measure of reported food intake in humans. *Appetite* 15: 103-13.

Meneely, E. A. and N. L. Kaltreider (1949). Volume of the lung determined by helium dilution. *Journal of Clinical Investigation* 28: 129-139.

Pannemans, D. L. and K. R. Westerterp (1993). Estimation of energy intake to feed subjects at enegy balance as verified by doubly labelled water: a study in the eldery. *European Journal of Clinical Nutrition* 47: 490-496.

Parker, B. A., K. Sturm, C. G. MacIntosh, C. Feinle, M. Horowitz and I. M. Chapman (2004). Relation between food intake and visual analogue scale ratings of appetite and other sensations in healthy older and young subjects. *Eur J Clin Nutr*. 58: 212-8.

Perneger, T. V. (1998). What's wrong with Bonferroni adjustments. *British Medical Journal* 316: 1236-8.

Provencher, V., V. Drapeau, A. Tremblay, J. P. Despres and S. Lemieux (2003). Eating behaviors and indexes of body composition in men and women from the Quebec family study. *Obesity Research* 11: 783-92.

Raben, A., A. Tagliabue and A. Astrup (1995). The reproducibility of subjective appetite scores. *Br J Nutr*. 73: 517-30.

Schoeller, D. A. (1995). Limitations in the assessment of dietary energy intake by self-report. *Metabolism* 44: 18-22.

Siri, W. E. (1956). The gross composition of the body. *Advance in Biology of Medicine and Physiology* 4: 239-280.

Stubbs, R. J., D. A. Hughes, A. M. Johnstone, E. Rowley, C. Reid, M. Elia, R. Stratton, H. Delargy, N. King and J. E. Blundell (2000). The use of visual analogue scales to assess motivation to eat in human sujects: a review of their reliability and validity with an evaluation of new hand-held computerized systems for temporal tracking of appetite ratings. *British Journal of Nutrition* 84: 405-415.

Tremblay, A., J. Sévigny, C. Leblanc and C. Bouchard (1983). The reproducibility of a three-day dietary record. *Nutrition Research* 3: 819-830.

Tuomisto, T., M. T. Tuomisto, M. Hetherington and R. Lappalainen (1998). Reasons for initiation and cessation of eating in obese men and women and the affective consequences of eating in every day situations. *Appetite* 30: 211-222.

Westerterp, K. R. and A. H. Goris (2002). Validity of the assessment of dietary intake: problems of misreporting. *Curr Opin Clin Nutr Metab Care* 5: 489-93.

Yeomans, M. R. (1996). Palatability and the microstructure of eating in humans: the appetiser effect. *Appetite* 26: 119-133.

Table 1 Description of the six weight loss studies (longitudinal data)

Studies	Subjects	Age (years)[1]	BMI (kg/m^2)[1]	Weight loss (kg)	Intervention	Time
#1	Men n = 47	43.2 ±1.0	32.0 ±0.4	-5.3 ±0.9	Drug (Topiramate)	1 year
#2	Men n = 44	45.6 ±1.5	31.7 ±0.4	-1.3 ±0.3	Drug (Rimonabant)	4 weeks
#3	Men n = 21	42.9 ±1.5	34.0 ±0.6	-9.9 ± 1.0	Diet + drug (Fenfluramine) / placebo	15 weeks
	Women n = 25	41.6 ±0.9	36.6 ±0.8	-7.0 ±1.1		
#4	Men n = 13	38.2 ±1.4	32.9 ±0.9	-9.1 ±1.2	Diet + physical activity	Until weight loss resistance (~ 30 weeks)
	Women n = 2	43.0 ±4.0	34.8 ±3.0	-5.0 ±0.7		
#5	Women n = 62	42.7 ±0.7	31.9 ±0.4	-3.6 ±0.4	Diet + calcium and vitamin D (caltrate) / placebo	15 weeks
#6	Men n = 17	36.8 ±2.0	33.6 ±1.2	-3.3 ±0.8	Diet + micronutrient supplementation / placebo	15 weeks
	Women n = 22	36.8 ±1.6	35.1 ±0.8	-4.0 ±0.9		
Group	Men n=142	42.7 ±0.6	32.5 ±0.3	-4.8 ±0.4	-	-
	Women n=111	41.3 ±0.7	33.7 ±0.3	-4.5 ±0.5		

[1] Age and BMI at baseline

Table 2 Characteristics of men and women (baseline data).

Variables	Men (n=176)	Women (n=139)
Subject's characteristics		
Age (years)	42.3 ±0.7	41.3 ±0.6
Body weight (kg)	98.7 ±0.9	86.6 ±1.0***
BMI (kg/m^2)	32.1 ±0.3	33.5 ±0.3*
Percent body fat (%)	32.0 ±0.4	43.7 ±0.5***
Appetite sensations in a fasting state		
Desire to eat (mm)	87.4 ±3.1	83.1 ±3.4
Hunger (mm)	92.3 ±3.1	86.6 ±3.5
Fullness (mm) [1]	31.1 ±2.2	25.4 ±2.5
PFC (mm) [1]	92.0 ±2.6	82.5 ±2.9*
1 h post meal area under the curve (1-h AUC, mm x min)		
1-h AUC for desire to eat	1965 ±117	1023 ±131***
1-h AUC for hunger [2]	2034 ±116	1018 ±130***
1-h AUC for fullness [2]	5308 ±159	6609 ±178***
1-h AUC for PFC	2488 ±131	1504 ±147***
Satiety quotient (SQ, mm/kcal)		
SQ for desire to eat	7.4 ±0.4	10.9 ±0.5***
SQ for hunger	7.9 ±0.4	11.5 ±0.5***
SQ for fullness [1, 2]	8.3 ±0.5	14.1 ±0.5***
SQ for PFC [1]	6.9 ±0.4	9.5 ±0.4***
Energy intake measurements		
Measured energy intake (kcal/buffet) [3]	1282 ±32	917 ±38***
Reported energy intake (kcal/day) [4]	2803 ±45	2375 ±51***

Mean ±SE. Significantly different from men * $p < 0.01$, ** $p < 0.001$; *** $p < 0.0001$. PFC: prospective food consumption. [1] women n= 138; [2] men n= 175; [3] men = 151 and women n= 108; [4] men = 174 and women n = 137.

Table 3

Correlation coefficients[1] between appetite sensation variables and ***ad libitum* energy intake** for the whole group and for men and women separately (baseline data).

Correlation coefficient	All group	Men	Women
Appetite sensations in fasting state			
Desire to eat	0.26 ***	0.17 †	0.40 ***
Hunger	0.17 *	0.10	0.28 *
Fullness	0.06	0.03	0.10
PFC	0.32 ***	0.30 **	0.37 ***
1h post meal area under the curve (1-h AUC, mm x min)			
AUC for desire to eat	0.32 ***	0.24 *	0.41 ***
AUC for hunger	0.30 ***	0.24 *	0.38 ***
AUC for fullness	-0.20 **	-0.09	-0.36 ***
AUC for PFC	0.26 ***	0.20 *	0.37 ***
Satiety quotient (SQ, mm/kcal)			
SQ for desire to eat	0.04	0.00	0.17
SQ for hunger	0.03	0.08	0.07
SQ for fullness	-0.14 †	-0.06	-0.22 *
SQ for PFC	0.06	0.10	0.07

Statistically significant *p ≤ 0.01; **p ≤ 0.001; ***p ≤ 0.0001 and tendency † p < 0.05.

PFC: prospective food consumption

[1] Correlation coefficients adjusted for body weight and the covariate "study".

Table 4

Correlation coefficients[1] between appetite sensation variables and **reported energy intake** for the whole group and for men and women separately (baseline data).

Correlation coefficient	All group	Men	Women
Appetite sensations in a fasting state (mm)			
Desire to eat	0.14 *	0.20 *	0.10
Hunger	0.14 †	0.20 *	0.00
Fullness	-0.14 *	-0.14 †	-0.17
PFC	0.17 *	0.24 **	0.08
1h post meal area under the curve (1-h AUC, mm x min)			
AUC for desire to eat	0.17 **	0.17 †	0.17 †
AUC for hunger	0.14 *	0.14 †	0.14
AUC for fullness	-0.20 **	-0.17 †	-0.22 *
AUC for PFC	0.20 **	0.17 †	0.20 †
Satiety quotient (SQ, mm/kcal)			
SQ for desire to eat	0.02	0.10	0.01
SQ for hunger	0.00	0.09	0.06
SQ for fullness	-0.08	0.02	-0.08
SQ for PFC	0.01	0.08	0.06

Statistically significant *$p \leq 0.01$; **$p \leq 0.001$; ***$p \leq 0.0001$ and tendency † $p < 0.05$.

PFC: prospective food consumption

[1] **Correlation coefficients adjusted for body weight and the covariate "study".**

Figure legends

Figure 1

Fasting appetite sensation before and after weight loss for men and women. Significantly different from before weight loss * $p \leq 0.01$; ** $p \leq 0.001$; *** $p \leq 0.0001$.

Figure 2

One-hour post meal area under the curve (AUC) before and after weight loss for men and women.

Figure 3

Satiety quotient (SQ) before and after weight loss for men and women. Significantly different from before weight loss ** $p \leq 0.001$;*** $p \leq 0.0001$.

Figure 1

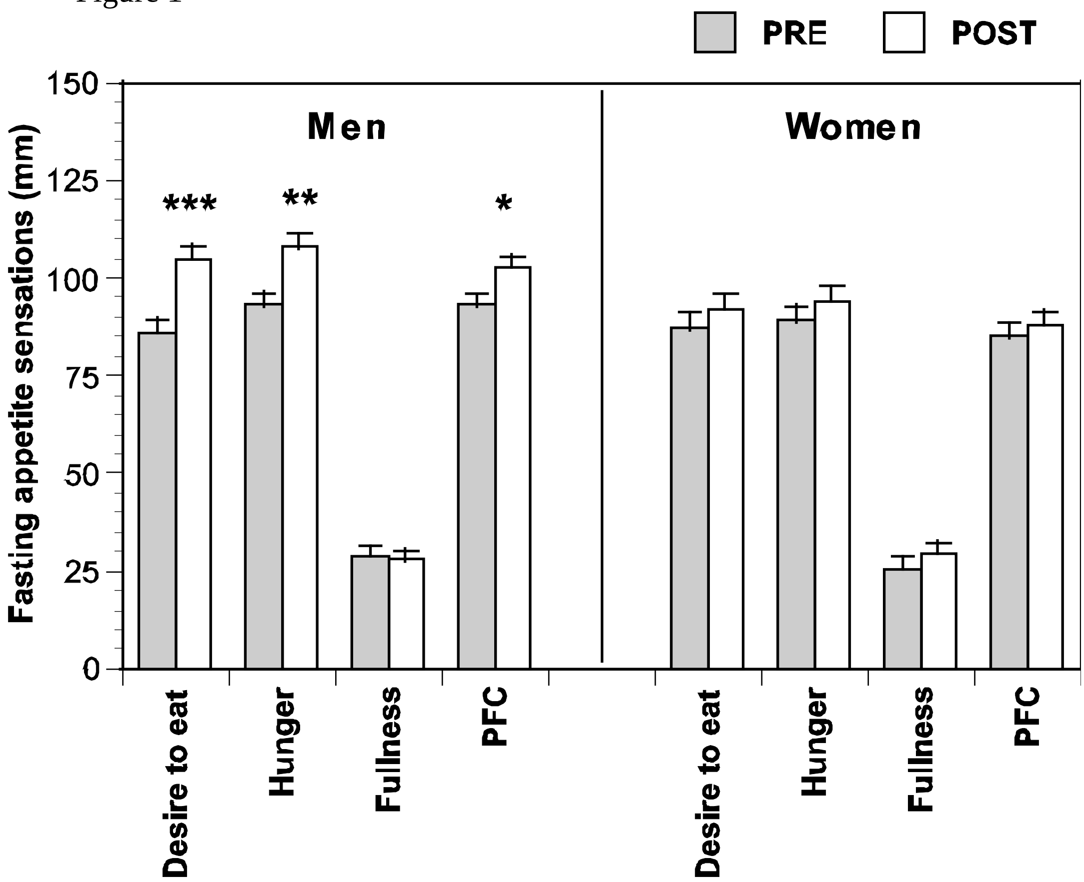
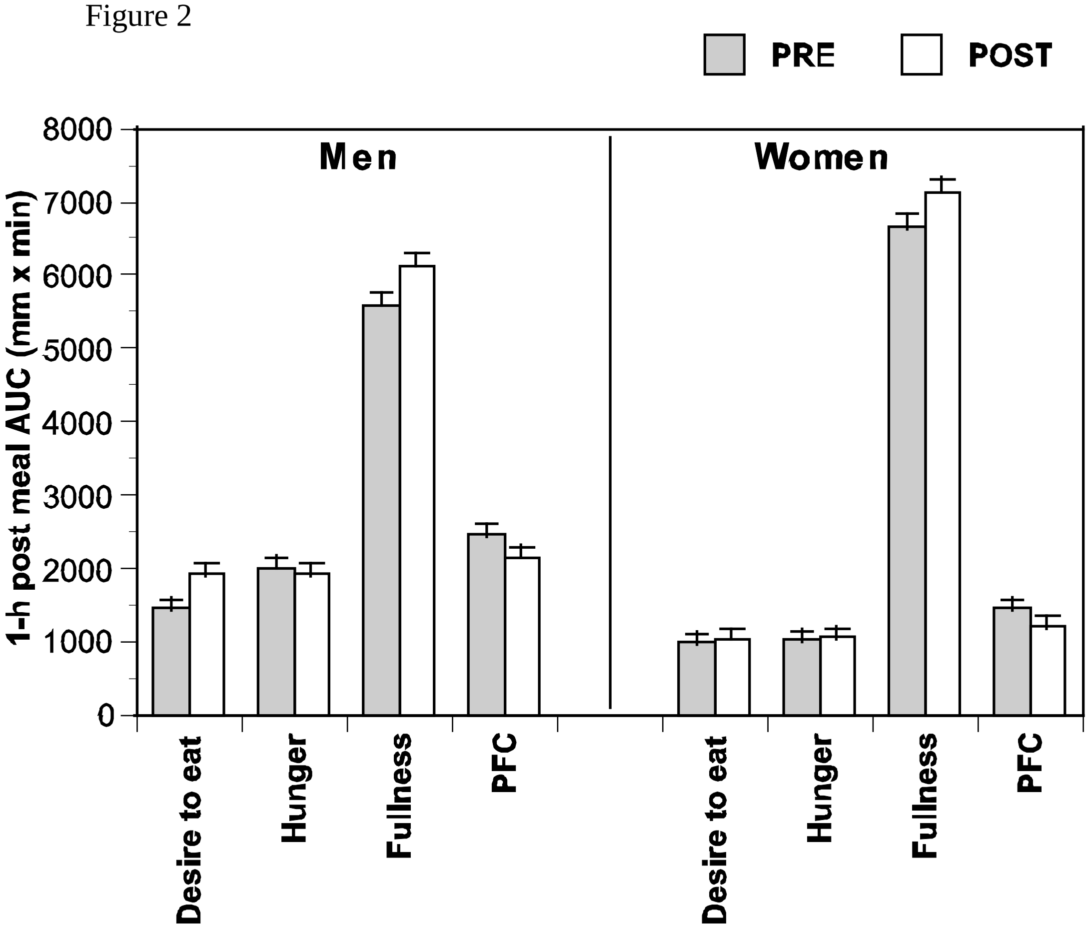
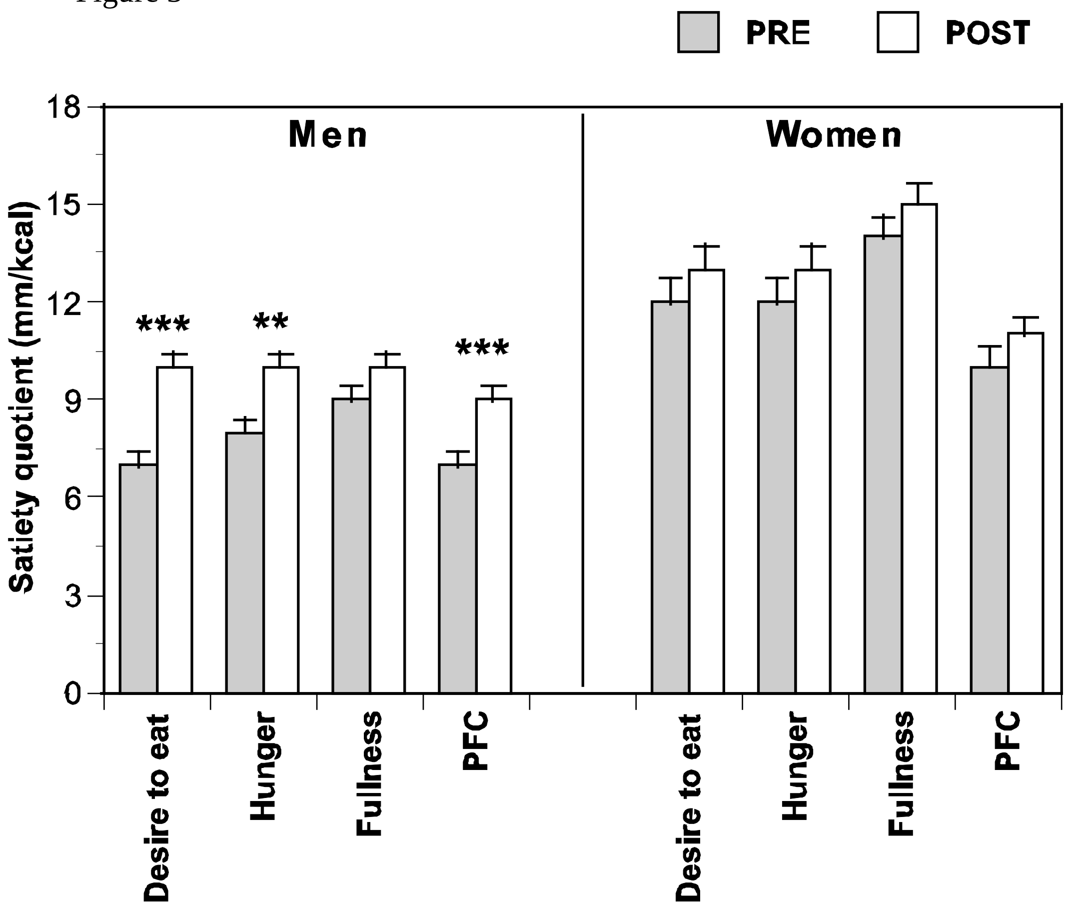

PRE
POST
Men
Women
Fasting appetite sensations (mm)
150
125
100
75
50
25
0
***
**
*
Desire to eat
Hunger
Fullness
PFC
Desire to eat
Hunger
Fullness
PFC

Figure 2



PRE
POST
Men
Women
1-h post meal AUC (mm x min)
8000
7000
6000
5000
4000
3000
2000
1000
0
Desire to eat
Hunger
Fullness
PFC
Desire to eat
Hunger
Fullness
PFC

Figure 3


PRE
POST
Men
Women
Satiety quotient (mm/kcal)
18
15
12
9
6
3
0
***
**
***
Desire to eat
Hunger
Fullness
PFC
Desire to eat
Hunger
Fullness
PFC