Appetite sensations as a marker of overall intake

Vicky Drapeau[1], John Blundell[2], Fanny Therrien[3], Claire Lawton[2], Denis Richard[3] and Angelo Tremblay[1]*

[1]*Division of Kinesiology, Laval University, Ste-Foy, Quebec, Canada, G1K 7P4*
[2]*Department of Psychology, Leeds University, Leeds, UK, LS2 9JT*
[3]*Department of Anatomy and Physiology, Laval University and Laval Hospital Research Center, Quebec, Canada, G1K 7P4*

The aim of this study was to evaluate the clinical utility of appetite sensations to characterize individual overall energy intake. A group of men (n 28) and women (n 23) was recruited to record their 'desire to eat', 'hunger', 'fullness' and 'prospective food consumption' (PFC) on visual analogue scales before a standardized meal test, immediately after and every 10 min for a period of 1 h after the meal. The 1 h post-meal area under the curve (1 h AUC) and the satiety quotient (SQ) were calculated for all appetite sensations. In a second visit, all participants were invited to eat three meals in order to measure total energy intake (TEI) and food preferences. Metabolic rate (MR) was also assessed to derive daily relative energy intake (REI) by subtracting this variable from TEI (TEI$-$MR$=$REI). The Three-Factor Eating Questionnaire scores were also calculated for all participants. One h AUC for fullness was the appetite sensation most strongly associated with TEI and REI ($r-0.42$, $P \leq 0.003$ and $r-0.32$, $P \leq 0.05$, respectively). SQ for fullness was the only predictor of TEI and REI ($r-0.42$, $P \leq 0.0003$ and $r-0.30$, $P \leq 0.05$, respectively). Restraint, disinhibition and hunger scores were not associated with appetite sensation variables. These results suggest that the fullness dimension seems to be a useful appetite sensation to predict long-term TEI and REI. Thus, assessment of appetite sensation such as fullness in response to a fixed load may be useful to evaluate individual overall energy intake.

Visual analogue scales: Appetite sensations: Satiety quotient: Energy intake: Overeating: Satiety

Obesity is caused by a combination of factors that inevitably result in an increase in energy intake and/or a decrease in energy expenditure. The assessment of energy intake is an important issue in the characterization of factors implicated in obesity. However, this component of energy balance is difficult to evaluate because under-reporting is common in reported energy intake (Westerterp *et al.* 1991; Pannemans & Westerterp, 1993; Johnson *et al.* 1994; Buhl *et al.* 1995; Schoeller, 1995). This phenomenon seems to be more important in certain populations such as obese (Lichtman *et al.* 1992; Heitmann & Lissner, 1995; Lafay *et al.* 1997) and restrained individuals (Lafay *et al.* 1997; Asbeck *et al.* 2002). In this context, there is a need to develop long-term indicators of total energy intake (TEI) in order better to characterize individual overall intake.

Appetite sensations, which reflect objective and subjective components of appetite control (Stubbs *et al.* 2000), may have some potential in the development of such a marker. When assessed before a meal, appetite sensations such as 'hunger', 'desire to eat' and 'appetite for a meal' have been shown to be associated with subsequent energy intake (Mattes, 1990; Hulshof *et al.* 1993; Barkeling *et al.* 1995;

Porrini *et al.* 1995). Post-meal appetite sensations also seem to be a good predictor of short-term measured energy intake (Flint *et al.* 2000). However, the clinical utility of appetite sensations to predict long-term food intake is still uncertain. Only one study has tested the potential utility of appetite sensations in a long-term nutritional follow-up in obese men and women (Doucet *et al.* 2003). In that study, post-meal appetite ratings predicted 24 h energy intake, which was measured as long as 2 weeks after the assessment of appetite sensations. However, this relationship was found only in reduced-obese men. Thus, the clinical utility of appetite sensations requires further investigation.

Appetite sensations measured before and after a meal can also reveal information about the satiating capacity of food, which can be expressed as satiety quotient (SQ). Kissileff (1984) first introduced the satiating efficiency of food, which aimed at measuring the extent to which a preload could reduce subjective appetite sensations per unit of intake (e.g. kcal, kJ). Green *et al.* (1997) extended this concept by taking into account the temporal effect of foods and suggested calculation of the SQ for each appetite sensation measured over time. Differences in SQ for hunger sensation have been observed between meals of high

and low fixed energy or *ad libitum* meals and between high- and low-restrained individuals (Green *et al.* 1997). The usefulness of the SQ needs to be investigated in other populations (e.g. obese). We think that this concept could represent a good marker of individual satiety signal capacity in response to a fixed meal test. In this context, SQ should be associated with long-term TEI: i.e. lower SQ reflecting impaired satiety signals and thus higher overall intake. The present study was therefore performed to further evaluate the clinical utility of appetite sensation responses to a meal test as a potential marker of individual long-term overall intake, and ultimately susceptibility to overeating.

Experimental methods

Subjects and procedures

The subjects who participated in this study were involved in another study that investigated the relationship between body weight and stress. Participants were recruited through advertisements placed at the University and in other locations in the Quebec City area. Eligibility of the participants was determined by a telephone interview. Inclusion criteria for the study were age 20–50 years, normal weight (BMI$\leq$27.0 kg/m^2), obese (BMI 30.0–35.0 kg/m^2) and/or reduced obese (BMI$\geq$30.0 kg/m^2), in apparently good health, free of medications, sedentary to moderately active (low-intensity physical activities such as brisk walking, three times weekly or less, no more than 30 min per session), no more than five cups of coffee daily, fewer than two alcoholic drinks daily or nine alcoholic drinks weekly, and premenopausal women. The reduced-obese subjects had lost a minimum of 5 kg in the past 6 months (mean 12.6 (SE 1.6) % of initial body weight) and were still trying to lose more weight or maintain their body weight. Participants were blind to the study objective. They were aware only of the original nature of the study, i.e. obesity and stress. Each subject received a financial compensation when the study was completed. All participants gave their written consent to take part in the study, which was approved by the Laval University Ethics Committee.

A group of men (*n* 28) and women (*n* 23) with BMI ranging from 18.5 to 43.4 kg/m^2 was invited to participate in two testing sessions which were separated by at least 2 weeks. Except for eight men and seven women, who were considered as reduced-obese subjects, all participants reported a weight variation of $\pm$4 kg for at least 2 months prior the study.

The first visit started with a standardized breakfast meal test. Thereafter, weight, height (bathing suit, without shoes), waist circumference (Lohman *et al.* 1988) and percentage body fat were assessed for each participant. Percentage body fat was determined by the underwater weighing technique. The Siri formula (Siri, 1956) was used to estimate percentage of body fat from body density. During this first visit, subjects were also asked to complete the Three-Factor Eating Questionnaire (TFEQ; Stunkard & Messick, 1985) as validated for the French population (Lluch, 1995), which permits determination of 'dietary restraint', 'disinhibition' and 'susceptibility to hunger' scores. The TFEQ has been shown to have good reliability

and validity (Stunkard & Messick, 1985; Laessle *et al.* 1989). A food preference questionnaire using a scale from 0 (don't like at all) to 5 (like very much) was used to make sure that all the participants liked the food presented in the study. Subjects scoring less than 3 for more than 50 % of the food items were excluded from this study.

Long-term TEI was measured in the second testing session, which, as stated above, was separated by at least 2 weeks from the first session. The second testing session included three meal tests (standardized breakfast, *ad libitum* lunch and *ad libitum* dinner) and the measurement of metabolic rate (MR), which corresponds to energy expenditure, was measured 3 h after the standardized breakfast. The use of MR three hours after a meal is considered highly significant in the context of the present study because it is measured at a moment when the subject wishes to eat. In addition, a high correlation has been observed between postprandial MR and RMR (*r* 0.90; Haugen *et al.* 2003). Consequently, the ability to classify individuals with postprandial MR is considered identical to what we could obtain if subjects were classified on the basis of the RMR measurement. For the two testing days, participants had to arrive at the laboratory in the morning after an overnight fast (12 h). Moreover, subjects were asked to refrain from alcohol consumption and intense physical activity 24 h before each testing session. All meals served in the laboratory were consumed under the same conditions: alone, in a quiet place, without reading materials.

Meal test and appetite sensations

The standardized breakfast was served between 07.30 and 09.30 hours in order to replicate the usual breakfast time of each participant (Appendix 1). The energy content of the meal test was 733 kcal (3067 kJ) and 599 kcal (2506 kJ) for men and women, respectively, and had a food quotient of 0.85. All participants were instructed to eat within 30 min or less. Before, immediately after and every 10 min for a period of 1 h after the standardized breakfast test, subjects were asked to record their appetite sensations such as 'desire to eat', 'hunger', 'fullness' and 'prospective food consumption' (PFC) on visual analogue scales adapted from Hill & Blundell (1986). Briefly, subjects were asked to indicate, on a scale from 0 to 150 mm, how they felt at the moment of completing the following 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 evaluate their appreciation of the meal.

The appetite ratings before the standardized meal test were taken as the fasting (baseline) appetite sensations. The appetite sensation responses to the standardized meal test were evaluated by calculating the 1 h post-meal area under the curve (1 h AUC) with the trapezoid method (Doucet *et al.* 2003). The satiety signal capacity was assessed with the SQ concept adapted from Green *et al.* (1997). In this study, the SQ was not investigated over time because of the rather short interval of appetite ratings

after the meal. Instead, we used the mean post-meal appetite sensations to evaluate SQ or the satiety signal capacity in response to a standardized meal test. In addition, SQ values were multiplied by 100 to obtain a more meaningful range of values. Thus, the SQ was calculated for each appetite sensation (AS) with the equation:

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

Consequently, the theoretical range of possible SQ values was -20 to 20 for men and -25 to 25 for women. A higher SQ for each appetite sensation would mean a greater satiety signal capacity for one individual whereas a lower SQ would represent a blunted satiety signal capacity.

Total and relative energy intake assessments

After at least a 2-week delay, TEI was calculated over a period of 12 h with one fixed and two *ad libitum* meals. First, the same standardized breakfast served at the first visit was provided for each subject and was taken between 07.00 and 08.00 hours at home. The participants were asked to arrive at the laboratory at 11.00 hours. At about 11.45 hours, the subject was invited to eat an *ad libitum* buffet-type meal for lunch to assess free energy intake and macronutrient preferences. After lunch, participants relaxed in a quiet room until dinner time. The *ad libitum* dinner was served about 4 h after the lunch. Appendix 2 presents the foods that were offered during each meal. Participants were instructed not to eat or drink anything else between the three meals, except water. All foods served *ad libitum* (lunch and dinner) were weighed before and after consumption. The Food Processor software (version 7.60, 2000; ESHA Research, Salem, OR, USA) was used to evaluate TEI during the day and macronutrient preferences at the lunch meal.

Before lunch, MR was determined for each subject by indirect calorimetry. After a 30 min resting period, expired gas was collected through a mouthpiece over a 15 min period. The nose was clipped for the entire sampling period. Pulmonary ventilation was determined using a K520 flow transducer (KL Engineering, Sylmar, CA, USA) and gases (CO_2 and O_2) were assayed with a Uras 10E analyser (Hartmann & Braun AG, Frankfurt, Germany). The analyser was calibrated before each test and the Weir formula (Weir, 1949) was used to determine the energy equivalent of O_2 volume. MR was used to derive relative energy intake (REI = TEI − MR), which represents TEI adjusted for each individual's energy expenditure.

Statistical analyses

ANOVA was used to assess age, body weight indicators, appetite sensation variables, energy intakes and macronutrient preference differences between men and women. Pearson correlations were performed to evaluate the associations between the appetite sensation variables (fasting state, 1 h AUC and SQ) and dependent variables (TEI, macronutrient preferences, REI and TFEQ scores) for the whole group and for men and women separately. Partial correlations adjusted for body weight and BM were also calculated to evaluate the same associations (except for REI). We decided not to use the Bonferroni correction because of the covariation between appetite sensation variables (Perneger, 1998) and there being a reasonable probability of finding an association between appetite sensation variables and energy intake (Stubbs *et al.* 2000). Stepwise multiple regression analyses (with a probability of 0·05) were also used to determine the best predictor of TEI and REI. All values are expressed as means with standard errors, and differences are considered significant at $P \le 0.05$. All analyses were performed using Jump Software 3.1.6.2 (SAS Institute Inc., Cary, NC, USA).

Results

Mean age and BMI were not different between men and women (Table 1). However, men had significantly lower percentage body fat and higher waist circumference than women. Women had higher restraint and disinhibition scores than men (Table 1).

Appetite sensation variables such as fasting, 1 h AUC and SQ were not significantly different between men and women (Table 2). TEI, especially during the lunch meal, and MR were higher in men than in women (Table 3). In general, subjects appreciated the meals offered (mean scores on visual analogue scales of 114 and 116 mm for men and women, respectively).

Table 1. Subject characteristics

(Mean values with their standard errors and range)

Variable	Men (*n* 28)			Women (*n* 23)		
	Mean	SE	Range	Mean	SE	Range
Age (years)	37·4	1·4	25−50	38·2	1·5	23−49
BMI (kg/m^2)	27·9	1·0	20·5−37·4	27·4	1·1	18·5−43·4
Percentage body fat	23·8	1·6	4·6−36·7	31·7**	1·8	12·3−49·0
Waist circumference (cm)	94·8	2·5	72·3−113·6	87·1*	2·8	64·2−124·1
Restraint (maximum score 21)	6·9	0·8	1−18	9·3*	0·9	3−16
Disinhibition (maximum score 16)	5·3	0·6	1−11	7·6**	0·6	2−13
Susceptibility to hunger (maximum score 14)	4·1	0·6	0−11	5·4	0·7	0−13

Mean values were significantly different from those of men: *$P < 0.05$; **$P < 0.01$.

Table 2. Appetite ratings in the fasting state, 1 h post-meal area under the curve (1 h AUC) and satiety quotient (SQ) for men and women

(Mean values with their standard errors)

Appetite sensation variables	Men (*n* 28) Mean	SE	Women (*n* 23) Mean	SE
Appetite ratings in the fasting state (mm)				
desire to eat	77·5	7·8	75·1	8·9
hunger	83·5	7·2	66·7	8·0
fullness	39·8	5·6	37·9	6·2
PFC	84·5	6·2	74·1	6·9
1 h AUC (mm × min)				
AUC for desire to eat	1302	203	990	223
AUC for hunger	1372	225	1115	248
AUC for fullness	6118	327	6349	361
AUC for PFC	2382	331	1439	365
SQ (mm/kcal)				
SQ for desire to eat	7·6	1·1	9·7	1·2
SQ for hunger	8·3	1·0	7·9	1·1
SQ for fullness	8·4	1·0	11·3	1·1
SQ for PFC	6·1	1·0	8·3	1·1

PFC, prospective food consumption.

The relationship between appetite sensations and energy intake variables was evaluated for the whole group and for men and women separately even though there was no significant interaction between genders. One h AUC was related with measured TEI in the whole group (Table 4). More specifically, desire to eat, hunger and PFC were positively correlated with TEI, whereas fullness was negatively related with this variable. The 1 h AUC for fullness represents the appetite sensation that was most strongly related to TEI. SQ for fullness was the only appetite sensation dimension for which we could observe a significant correlation with TEI (Table 4). The same trend was found when men and women were considered separately (Table 4). However, the relationships between SQ for fullness and TEI were no more significant probably because of the smaller subject number. Adjustment for body weight and BMI decreased the strength of the associations observed between 1 h AUC or SQ and TEI. However, the association found between 1 h AUC for fullness and TEI

Table 3. Total energy intake (TEI; standardized breakfast, *ad libitum* lunch and dinner), metabolic rate (MR), relative energy intake (REI; = TEI − MR), energy intake (EI) and macronutrient preferences at the buffet-type lunch for men and women

(Mean values with their standard errors)

Variable	Men (*n* 28) Mean	SE	Women (*n* 23) Mean	SE
TEI (kcal/d)†	2634	85	2081***	102
(kJ/d)	11 015	357	8699***	425
MR (kcal/d)‡	1962	53	1628***	59
(kJ/d)	8204	221	6810***	246
REI (kcal/d)§	676	102	503	119
(kJ/d)	2828	411	2106	498
EI at lunch (kcal)	1113	61	795**	67
(kJ)	4654	255	3325**	281
Carbohydrates at lunch (% TEI)	42·0	1·8	39·6	1·9
Lipids at lunch (% TEI)	35·9	1·4	39·6	1·5
Proteins at lunch (% TEI)	22·1	1·3	20·8	1·1
EI at dinner (kcal)†	779	50	630	60
(kJ)	3258	209	2635	251

Mean values were significantly different from those of men: **$P < 0.001$; ***$P < 0.0001$.
† Men, *n* 27; women, *n* 19.
‡ Men, *n* 26; women, *n* 21.
§ Men, *n* 25; women, *n* 17.

was still significant, except for the men. Relationships between 1 h AUC or SQ for all appetite sensations and REI also revealed that only 1 h AUC or SQ for fullness was associated with REI (Fig. 1(a) and (b)). The same pattern of relationship was observed when considering macronutrient intake and dietary densities as dependent variables (data not shown).

Even though adjustments for body weight and BMI affected our results, no consistent pattern of correlation was found between appetite sensation variables (1 h AUC or SQ) and participant characteristics such as body weight, BMI, percentage body fat and MR, either in the whole sample or for each sex separately. In women, body weight was negatively correlated with SQ for desire to eat ($r - 0.46$, $P=0.03$) and SQ for PFC ($r - 0.49$, $P=0.02$) only, and BMI was negatively correlated with

Table 4. Correlation coefficients between appetite sensations and total energy intake for the whole group and for men and women separately: non-adjusted (NA) and adjusted (A) for body weight and BMI

	Whole group NA	A	Men NA	A	Women NA	A
1 h AUC (mm × min)						
AUC for desire to eat	0·30*	0·17	0·20	0·14	0·38	0·36
AUC for hunger	0·37**	0·24	0·36	0·26	0·46*	0·42
AUC for fullness	− 0·42***	− 0·32*	− 0·42*	− 0·28	− 0·61**	− 0·54**
AUC for PFC	0·33*	0·17	0·20	0·20	0·35	0·37
SQ (mm/kcal)						
SQ for desire to eat	0·03	0·26	0	0	0·20	0·37
SQ for hunger	0·03	0·08	0	0·14	0·05	0·17
SQ for fullness	− 0·42***	− 0·26	− 0·35	− 0·30	− 0·39	− 0·32
SQ for PFC	0·20	0·05	0·09	0·10	0·10	0·02

1 h AUC, 1 h post-meal area under the curve; PFC, prospective food consumption; SQ, satiety quotient.
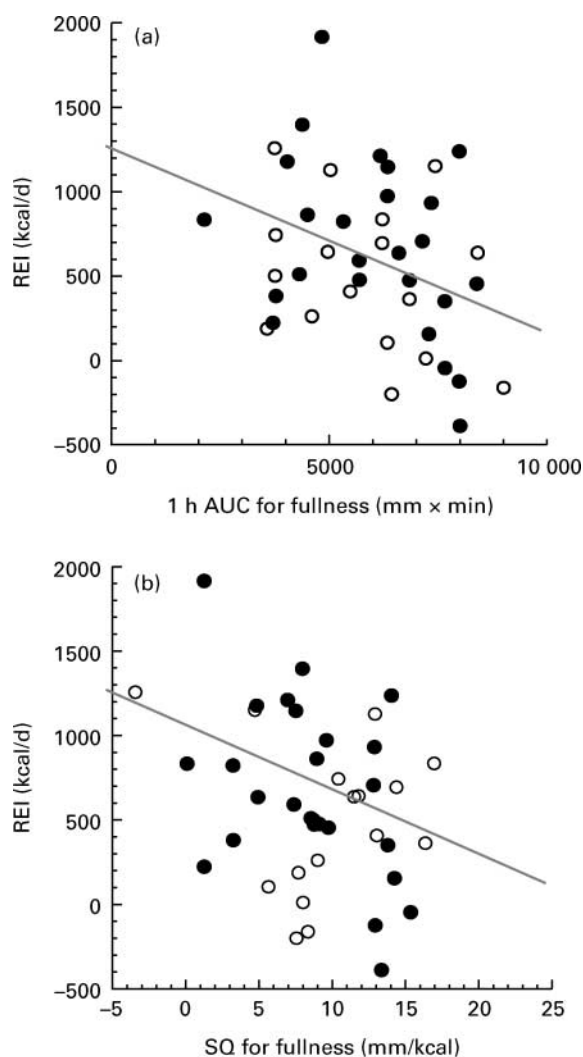Statistically significant correlation: *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Fig. 1. Relationship between relative energy intake (REI) and (a) 1 h post-meal area under the curve (1 h AUC) for fullness and (b) satiety quotient (SQ) for fullness in men (●) and women (○). Correlation between REI and 1 h AUC for fullness: $r - 0.32^*$, -0.36 and -0.30 for the whole group, men and women, respectively. Correlation between REI and SQ for fullness: $r - 0.30^*$, -0.42^* and -0.08 for the whole group, men and women, respectively. Statistically significant correlation: $^*P \leq 0.05$.

SQ for PFC ($r - 0.49$, $P = 0.02$). In men, only BMI was positively correlated with SQ for fullness (r 0.44, $P = 0.02$). No association was found between appetite sensation variables (1 h AUC and SQ) and MR in men. In women, MR was positively correlated with 1 h AUC for PFC (r 0.42, $P = 0.05$), and negatively correlated with SQ for desire to eat ($r - 0.64$, $P = 0.002$) and SQ for PFC ($r - 0.69$, $P = 0.0005$).

Because appetite sensation related to fullness represented the best predictor of TEI, we further examined this appetite sensation variable. SQ for fullness was negatively correlated with percentage lipid intake in women ($r - 0.60$, $P = 0.002$). The fullness SQ was also correlated with fullness 1 h AUC (whole group, r 0.55; men, r 0.72; women, r 0.40, $P(0.0001)$. In general, 1 h AUC and SQ for fullness were not related with any TFEQ score. In a stepwise model including body weight, BMI, 1 h AUC

and SQ for fullness, the 1 h AUC for fullness explained an additional 7 % of the variance in TEI ($P \leq 0.05$) after body weight and BMI had explained 32 % of the variance whereas only the 1 h AUC for fullness explained 10 % of the variance in REI ($P \leq 0.05$). The addition of one or more TFEQ scores in the stepwise model did not influence these results.

Discussion

This study was performed as a first step in evaluating the usefulness of appetite sensations measured at a meal test to predict individual overall energy intake. Post-meal appetite sensation for fullness was found to be a good predictor of TEI measured after a relatively long delay (>2 weeks) following the assessment of appetite sensations. Such a delay between the appetite sensation assessment and energy intake was a significant feature of this study because it represents an important dimension to consider when the results are transposed in a clinical context. Appetite sensations for fullness also predicted REI, which suggests that some individuals expressed higher overall energy intake. Overeating can be a concept difficult to measure accurately, particularly in a cross-sectional context. In this study, we used the amount of energy consumed over MR as a measure of REI. This variable is not a direct measurement of overeating. However, since the participants tested in this study were all sedentary to moderately active and reported a weight variability offering different states of energy balance (± 4 kg), higher differences between TEI and MR are expected to represent an estimate of excess energy intake or higher overall energy intake.

Our results are in accordance with those of Doucet et al. (2003), who showed that 1 h AUC for all appetite sensations was associated with TEI measured up to 2 weeks after the appetite ratings. However, this was found only in reduced-obese men when evaluating obese men and women before and after a weight-loss intervention. In addition, the correlations found in that study were higher than those in the present study ($0.70 - 0.90$ v. $0.35 - 0.41$). The different foods offered to measure TEI, the longer period of time between the meal test and the energy intake measurement for some subjects in our study, and a different testing environment could partly explain these different results. The fact that our subjects were not engaged in a weight-loss intervention could also have influenced our results. It has been shown that restraint scores are higher in individuals seeking participation in weight-loss interventions (Boschi et al. 2001) as well as in reduced-obese individuals (Bjorvell et al. 1994; Clark et al. 1994; Pekkarinen et al. 1996; Wadden et al. 1997; Foster et al. 1998; Kiernan et al. 2001). In our study, we did not observe a strong influence of TFEQ scores on appetite sensation responses after the meal test. It is therefore possible that in our population the level of restraint was not as high as that in obese individuals before and after a weight-loss intervention, even in our reduced-obese group. Because the weight loss in the reduced-obese group had been achieved over the previous 6 months, their levels of restraint could have been lower at the moment of the testing than during or immediately after

their weight loss. The fact that the mean restraint score of men and women in our study was comparable with that found in normal-weight non-dieters (Klem *et al.* 1998) supports this assumption.

It should also be stated that TEI at a meal can be influenced by factors other than appetite sensations and eating behaviours, such as palatability, external factors, gender, body weight and genes (de Castro, 1993; Yeomans, 1996; Tuomisto *et al.* 1998; Jéquier & Tappy, 1999). The fact that our subjects ate their meals *ad libitum* under the same laboratory conditions probably attenuated the impact of external factors on food intake measurements. In addition, we did not find a gender interaction for the relationship between appetite sensations and TEI or REI. In this study, body weight and BMI could explain in part the relationship between appetite sensations and TEI. However, since 1 h AUC for fullness was still associated with TEI after body weight and BMI adjustments, and we did not observe a clear pattern of relationship between appetite sensations and participant characteristics, it is likely that individuals showing lower 1 h AUC for fullness expressed higher overall energy intake regardless of their current body weight. These results suggest that these individuals could be at higher risk of overeating. The negative relationships found between 1 h AUC for fullness and REI support this hypothesis.

The SQ was used in this study to measure satiety signal capacity. In the same way as the 1 h AUC, we found that the SQ for fullness was the most sensitive to predict TEI as well as REI. This could be explained by the fact that fullness is probably the easiest appetite sensation to detect because it is more physical (i.e. related with stomach fullness) than the other three motivational measures. Accordingly, fullness sensation has been identified as one of the most common reasons to stop a meal (Tuomisto *et al.* 1998). In addition, the higher SQ for fullness was also associated with lower fat preferences in women. It is, however, impossible to identify which comes first. Since a high-fat diet has been associated with excess energy intake and lower satiating capacity (Lawton *et al.* 1993), it could be argued that a habitual high-fat diet explains the lower satiety signal capacity shown by the fullness SQ. On the other hand, an impaired satiety signal capacity could predispose to overeating and thus to a high fat consumption. Nevertheless, the SQ for fullness seemed to measure a separate construct of appetite sensation response to a meal since it was not highly correlated with 1 h AUC for fullness. This is probably due to the fact that the SQ takes into account pre-meal appetite feelings, which is not the case for 1 h AUC.

The fact that we did not find an impact of restraint scores on SQ could be surprising since this behaviour has been shown to influence energy intake (Provencher *et al.* 2003). In contrast to our result, Green *et al.* (1997) found that restraint score did influence SQ. They observed higher SQ for hunger over time after a lunch with lower fixed energy compared with higher fixed energy in highly restrained normal-weight women, whereas there was no difference for unrestrained women. The fact that testing was performed in different populations and that the mean restraint score in our study was not so high could be responsible for these apparently diverging results.

It is interesting to note that we found very low fullness SQ values for some subjects (see Fig. 1(b)). This means that some subjects experienced almost no change in fullness after the meal. This is unlikely to be due to a misinterpretation of the question, because the research assistant reviewed these answers with the subjects to make sure that they had fully understood the question. These subjects were reporting that food could sometime stimulate their appetite. This phenomenon may have occurred in previous studies but may have been overlooked because mean group values are usually presented instead of individual mean values. This can only be seen when subjects are examined individually. We also cannot discard the fact that perhaps the amount of food served at this meal test was insufficient for some subjects. However, if the amount of food had been insufficient, we should have seen a clear negative relationship between SQ for fullness and body weight, which was not the case. In the context of this study, lower SQ could suggest that some individuals had impaired satiety signals (for fullness) which results in higher TEI and REI. Even if genetic influences have been found for appetite sensations such as hunger before and after meals (de Castro, 1999), it is difficult to determine if a lower satiety capacity is the cause of higher TEI because TEI itself could influence appetite sensations. These individuals display an interesting phenotype for further studies.

One objective of this study was to develop a simple, easy to administer and inexpensive clinical test that could predict individual overall long-term energy intake. One limitation of this study could be related to the standardized breakfast test, which is probably not the optimal tool to use in experimental settings because it does not consider differences in subjects' normal meal size and/or body weight. Nevertheless, this test has the potential to discriminate differences in energy intake over the rest of the day since we used *ad libitum* lunch and dinner to measure spontaneous energy intake. The use of a standardized breakfast also has the advantage of decreasing social bias that could be observed with an *ad libitum* meal test. Another possible limitation of this study concerned the potential impact of the artificial meal pattern employed to measure food intake (one fixed meal and two *ad libitum* meals). We are aware that this method does not permit reproduction of participants' normal eating pattern such as meal sizes, meal frequencies and temporal distribution. Nevertheless, this strategy has the advantage of standardizing the eating pattern and mimicking free-living conditions to some extent. This is supported by the fact that we found a positive relationship between TEI (after fixed breakfast, *ad libitum* lunch and dinner) and mean TEI derived from a 3 d dietary record (r -0.51, $P=0.0006$) that was completed in the initial study. In the context of this study, a non-standardized meal pattern could represent a confounding factor that could have decreased the likelihood of finding such a relationship. It is also important to consider the short period (4–5 h) of free food intake measurement used in this study. Accordingly, this method, which permits evaluation of free food intake only over two consecutive meals, could limit extrapolation of these results to individual overall diets. Finally, even if we did not find

relationships between appetite sensation and TFEQ scores, some eating behaviours, particularly restraint level, could have influenced measured energy intake and thus may have blunted the ability to identify associations. It is not excluded that the TFEQ scores could influence appetite sensations in other contexts and/or populations.

In summary, this study suggests that appetite sensation responses to a test meal could be useful in a clinical context to predict individual overall long-term energy intake. Appetite sensation regarding fullness (1 h AUC and SQ) seems to be the best marker of TEI variations. Ultimately, appetite sensations could also help to characterize individuals expressing higher REI and thus a higher susceptibility to overeat. Other longitudinal studies should be performed to confirm these findings. Furthermore, the SQ concept, which represents an individual's satiety capacity, merits attention in other studies investigating different phenotypes or different meal test challenges.

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Appendix 1

Composition of the breakfast meal test for men and women

	Men			Women		
		Energy			Energy	
Food	Weight (g)	kcal	kJ	Weight (g)	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

Appendix 2

Foods served during each meal for the assessment of total energy intake

Standardized breakfast (07.00–08.00 hours)		*Ad libitum* lunch (12.00 hours)		*Ad libitum* dinner (17.00 hours)
White bread	Turkey (slice)	Butter	Strawberry yoghurt (1·5 % fat)	Meat lasagne
Butter	Ham (slice)	Mayonnaise	Crisps	Chocolate granola bars
Peanut butter	Salmon mousse	Ketchup	Apples	Water
Cheddar cheese	Liver pâté	Italian dressing	Oranges	
Orange juice	Gruyere cheese (28 % fat)	Mustard	Milk (2 % fat)	
	Mozzarella cheese (17 % fat)	Salad	Orange juice	
	Cottage cheese (2 % fat)	Tomatoes	Dark soda	
	White bread	Carrots	White soda	
	Whole-wheat bread	Butter biscuits	Water	
	Soda crackers	Chocolate fudge cookies		