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Ghrelin levels are associated with hunger as measured by the Three-Factor Eating Questionnaire in healthy young adults☆,☆☆

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ABSTRACT

Weight gain and appetite regulation are complex interplays between internal and external cues. Our aim was to investigate the association of eating behaviors with ghrelin taking into account lifestyle. We conducted a cross-sectional analysis in a sample of first-year university students at the Université de Sherbrooke. We collected medical history, anthropometric measurements, vital signs, fitness index, and fasting blood samples. Questionnaires included a lifestyle questionnaire and the Three-Factor Eating Questionnaire (TFEQ) estimating dietary restraint, disinhibition and hunger. We recruited 308 participants aged 20.7 ± 3.2 years and a mean BMI of 23.3 ± 3.4 kg/m^2. Hunger score was significantly associated with ghrelin levels ($r = 0.11$, $P < 0.05$). In women, this association was independent of age, BMI, dietary and lifestyle factors ($P = 0.02$). The association between ghrelin level and hunger score was observable in leaner individuals ($r = 0.28$, $p < 0.0001$) but not in heavier individuals ($r = -0.08$, $p = 0.34$; stratified by BMI < vs > 22.6 kg/m^2). Restraint (R) and disinhibition (D) were not associated with ghrelin levels. The three eating behaviors demonstrated expected correlations with lifestyle supporting the validity of the TFEQ in this cohort. In conclusion, we demonstrated that ghrelin, a biological marker, is associated with self-reported perception of hunger, independently of anthropometric measures and lifestyle.

1. Introduction

The obesity epidemic has become a major public health problem and the increasing prevalence of obesity in children and young adults is particularly concerning [1]. Secular trends have brought great attention and questioning on etiological issues implicated in this epidemiologic rise in obesity. A positive energy balance from increased food intake and sedentary lifestyle is mainly incriminated; numerous determinants of this caloric imbalance are implicated and include metabolic and hormonal, social, behavioral and emotional variables [2,3].

Our environment is characterized by easy access to food and constant food-related publicities influence our food choices and are certainly partly responsible for the recent trend. Schachter's theory of "internal–external" eating refers to the integration by the individual of physiological/biological signals and external cues such as palatability [2,4,5]. According to this theory, normal-weight people are able to closely balance these influences whereas obese individuals fail to control these influences. Notably, the appetite rise prior to meals involves a complex interplay between exogenous and endogenous stimuli such as hormonal influences [6]. Ghrelin is the only known gastrointestinal hormone with putative orexigenic function and is mainly produced by gastric cells prior to food intake [7]. It seems that ghrelin regulation is disrupted in individuals with excess weight [8–14] but it is unknown whether ghrelin may be associated with specific eating behaviors in healthy individuals and may contribute to weight regulation in the early path leading to excess weight gain and obesity. Based on a cohort of healthy young adults, we investigated specific factors influencing eating behaviors as evaluated by the Three-Factor Eating Questionnaire (TFEQ). The TFEQ is a tool widely used to quantify three different concepts capturing internal cues that affect food intake: dietary restraint, disinhibition, and hunger [15]. In this study, we tested associations between these specific factors and ghrelin levels, taking into account potential confounding factors such as adiposity and various lifestyles (diet, physical activity, sedentary time and sleep).

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2. Subjects and methods

We are reporting in this paper the cross-sectional analyses of baseline data from a randomized control trial (NCT00995462). We recruited students that were registered in first year of undergraduate studies at the Université de Sherbrooke (Canada). Exclusion criteria included pregnancy, active chronic disease (ex. diabetes) or use of any medication that could affect weight (other than birth control pills). Individuals with a wide range of body mass index (BMI) were included (BMI was not an exclusion criteria and was ranging from 16.2 to 39.7 kg/m^2 in our sample). Recruitment was on a voluntary basis and each participant gave written consent. The study was approved by the *Centre hospitalier universitaire de Sherbrooke* and *Université de Sherbrooke* ethics review board of research on humans.

Personal and familial medical histories were collected by a physician. All anthropometric and laboratory measurements were taken after an 8-hour overnight fast. Height (in m) was measured with a wall stadiometer; weight (in kg) was measured with an electronic scale (in light street clothing and without shoes). Waist circumference was measured midway between the last rib and the top of the iliac crest with a flexible tape to the nearest 0.5 cm in standing position; measurements were done twice and the average of the 2 measurements was used for analyses. Lean body mass (in kg) was measured by standing electric bioimpedance (Tanita weight scale model TBF-300A). Blood pressure was measured twice after the participants were sitting for at least 5 min; the average of 2 measures was used for analyses. Blood samples were taken after a >8 h overnight fast and were stored at −80 °C for future analyses. Total ghrelin was measured by RIA (Linco).

Usual dietary habits (frequency of intake of key food categories) and leisure energy expenditure were self-reported using a questionnaire based on the 2004 Canadian Communities Health Survey (CCHS) performed by Statistics Canada [16]. The physical activity section of the survey specifically inquires about the frequency and duration of active traveling, recreational and sedentary activities. The step test from the Canadian Home Fitness Test [17] was used to estimate the fitness level of the participants by calculating a predicted aerobic capacity (VO_2) value.

Eating behaviors were evaluated by the Three Factor Eating Questionnaire (TFEQ), a validated tool to measure three different eating patterns [15,18] and we used the validated French version of the questionnaire [19]. The TFEQ consists of 51 questions about dietary practice encompassing three categories: restraint (21 items), disinhibition (16 items) and hunger (14 items). A score is summed for each behavior. Dietary restraint refers to conscious strategies to limit intake and achieve weight control or weight loss. Disinhibition applies to loss of control over eating and inability to control emotional cues. Finally, hunger reflects the perception of hunger feelings and how the individual can cope with these thoughts to modulate food intake.

2.1. Statistical analyses

Baseline characteristics are presented as mean and standard deviation (SD) for the overall cohort, then for men and women. We compared characteristics from men and women using Student's T-test if normally distributed; otherwise, we used Wilcoxon rank-sum test. We used Pearson's correlation equation to test univariate associations between each eating behavior score (hunger, restraint, or disinhibition) and ghrelin (continuous). Subsidiary analyses were performed in sub-groups (per sex and in low vs high BMI, stratified by median BMI). Finally, we conducted linear regression multivariate models to assess the influence of possible confounders on the association between eating behaviors and ghrelin levels. We constructed three models to correct for different confounders: model 1 to correct for age and sex, model 2 for age, sex and BMI and model 3 for age, sex, BMI, fitness level, frequency of fruits and vegetables, restaurant and fast food meals consumption, hours of sleep, leisure energy expenditure and fitness level. Variables were included in model 3 if they were associated with either one of the factors of the TFEQ or with ghrelin levels. In our linear regression models, we used ghrelin in continuous units, such as beta values correspond to score of eating behavior per pmol/L of increment of ghrelin. We considered P values<0.05 to be statistically significant. Analysis were done using SPSS version 17.0.

3. Results

Participants in the study were young adults (mean age was 20.7 ± 3.2 years old at baseline), 96% were of Caucasian ethnicity and mean BMI was in the healthy range: 23.3 ± 3.4 kg/m^2 (see Table 1). There was no statistically significant difference between men's and women's BMI (men: 23.7 ± 3.1, women: 23.1 ± 3.4; P=0.20) but men had a higher mean waist circumference (80 ± 8 cm vs 74 ± 8 cm in women; P<0.001) and a higher lean mass percentage (85 ± 5% vs 74 ± 7% in women; P<0.001). Ghrelin levels were similar in women and men (1264 ± 498 pmol/L in women vs 1186 ± 401 pmol/L in men; P=0.20). Women reported eating fruits and vegetables more frequently than men, men reported to be more active and had a higher fitness index (see Table 1). According to the TFEQ, women reported higher restraint (R) and disinhibition (D) scores than men (R: 8.9 vs. 6.8, P<0.0001; D: 6.9 vs. 4.9, P<0.0001) but no significant gender difference in hunger (H) score was found (H: 5.4 vs. 4.8, P=0.20).

Correlations of ghrelin levels with eating behavior and other variables (anthropometric measures and lifestyles indices) in our population are reported in Table 2 for the overall cohort, then for women and for men separately. Higher ghrelin levels were associated with higher hunger score on the TFEQ in the overall cohort (r=0.11; P=0.048, see also Fig. 1); this effect was not significant in either men or women separately (women R=0.11, P=0.09; men R=0.09, P=0.40). Neither dishinbition nor restraint scores were significantly correlated to ghrelin levels. Among other factors, higher BMI was associated with lower ghrelin levels (R=−0.16; P=0.006); this association was significant in women (R=−0.21; P=0.002). On the same line, lower ghrelin levels were associated with higher waist

Table 1
Characteristics of healthy young adults, admitted to Universite de Sherbrooke.

	Overall cohort	Women	Men
	Mean SD	Mean SD	Mean SD
N	308	228	80
Age (years)	20.7 ± 3.2	20.5 ± 2.3	21.8 ± 5.0
Anthropometric profile			
Waist circumference* (cm)	75.2 ± 8.7	73.6 ± 8.3	79.8 ± 8.3
Lean mass* (%)	75.4 ± 8.0	74.4 ± 7.2	82.5 ± 7.6
BMI (kg/m^2)	23.3 ± 3.4	23.1 ± 3.4	23.7 ± 3.1
Metabolic profile			
Ghrelin (pmol/L)	1244 ± 475	1264 ± 498	1186 ± 401
Dietary habits			
Frequency of fruits and vegetables* (per day)	5.4 ± 2.5	5.6 ± 2.6	4.9 ± 2.0
Breakfast (per week)	6.4 ± 1.2	6.4 ± 1.3	6.5 ± 1.0
Restaurant (per month)	3.8 ± 3.4	3.8 ± 3.6	3.7 ± 2.6
Fast food (per month)	1.3 ± 1.6	1.3 ± 1.6	1.4 ± 1.4
Physical activity profile			
Sleep (hours per night)	7.9 ± 0.9	8.0 ± 0.8	7.7 ± 0.9
Leisure physical activity* (Mets per week)	2.27 ± 1.78	2.12 ± 1.67	2.71 ± 2.00
Predicted aerobic capacity* (VO_2 in mL/kg/min)	44.5 ± 6.0	42.3 ± 0.3	50.7 ± 5.1
TFEQ results—factors influencing eating behavior			
Restraint* (score/21)	8.4 ± 4.4	8.9 ± 4.4	6.8 ± 4.2
Disinhibition* (score/16)	6.4 ± 3.0	6.9 ± 3.1	4.9 ± 2.3
Hunger (score/14)	5.2 ± 3.1	5.4 ± 3.2	4.8 ± 3.0

BMI: body mass index; TFEQ: Three-Factor Eating Questionnaire.
* significant difference between men and women p<0.05.