A systematic review of the use of the Satiety Quotient

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Abstract

The satiating efficiency of food has been increasingly quantified using the Satiety Quotient (SQ). The SQ integrates both the energy content of food ingested during a meal and the associated change in appetite sensations. This systematic review examines the available evidence regarding its methodological use and clinical utility. A literature search was conducted in 6 databases considering studies from 1900 to April 2020 that used SQ in adults, adolescents and children. All study designs were included. From the initial 495 references found, 52 were included. Of the studies included, 33 were acute studies (29 in adults and 4 in adolescents) and 19 were longitudinal studies in adults. A high methodological heterogeneity in the application of the SQ was observed between studies. Five main utilizations of the SQ were identified: its association with i) energy intake; ii) anthropometric variables; iii) energy expenditure/physical activity; iv) sleep quality and quantity; as well as v) to classify individuals by their satiety responsiveness (i.e. low and high satiety phenotypes). Altogether, the studies suggest the SQ as an interesting clinical tool regarding the satiety responsiveness to a meal and its changes in responses to weight loss in adults. The SQ might be a reliable clinical indicator in adults when it comes to both obesity prevention and treatment. There is a need for more standardized use of the SQ in addition to further studies to investigate its validity in different contexts and populations, especially among children and adolescents.

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Abbreviations

BF: Breakfast

BW: Body Weight

EI: Energy Intake

SQ: Satiety Quotient

SQ_{DTE}: Satiety Quotient for desire to eat

SQ_{F}: Satiety Quotient for fullness

SQ_{H}: Satiety Quotient for hunger

SQ_{PFC}: Satiety Quotient for prospective food consumption

SQ_{S}: Satiety Quotient for satiety

T1D: Type 1 diabetes

T2D: Type 2 diabetes

VAS: Visual analogue scale

Introduction

According to the World Health Organization, 39% of adults were overweight and 13% had obesity in 2016 [1] with pediatric data being just as concerning with 340 million children from 5 to 19 years old classified with overweight and obesity world-wide [1]. This alarming prevalence of overweight, obesity and their associated metabolic complications call for a better understanding of the mechanisms involved to propose innovative and effective weight loss strategies. Among them, the regulation of energy balance [2,3] and the pathways involved in the control of appetite and energy intake (EI) have been of particular interest over the last years [4]. Both homeostatic and hedonic mechanisms influence the motivation to eat (hunger), meal size (satiation) and post-meal suppression of hunger (satiety) [5].

Indeed, a number of objective and subjective methods have been developed for the quantification and evaluation of both food intake (e.g. ad libitum test meals, food diaries) and appetite sensations (e.g. visual analogue scales; VAS). These VAS usually comprise of questions pertaining to hunger “How hungry do you feel?”, fullness “How full do you feel?”, desire to eat “How strong is your desire to eat?”, and prospective food consumption “How much do you think you could eat?”, with “not at all” to “extremely” as labelled end points. Integrating both the energy content of food ingested during a meal and the associated change in appetite sensations, Green and collaborators developed a Satiety Quotient (SQ) as an indicator of the satiating efficiency of food [6]. The SQ is calculated by dividing the change in subjective appetite sensations in response to a meal by the energy content of the meal.

Since its development, there has been an increasing use of the SQ. While initially created as an indicator for the satiating efficiency of a meal or food, the SQ has been associated with food intake [7–10] and body weight (BW) and composition [9,11,12] or used as a tool to classify individuals by their satiety responsiveness [13–15]. However, the extent to which the SQ has been applied in research and its scientific and clinical relevance has yet to be examined. Therefore, the aim of this systematic review is to review the available evidence of the different contexts in which the SQ has been utilized in research, the methodologies used to calculate the SQ, and to examine its clinical utility.

Methods

This review is registered in the PROSPERO database as CRD42019136442. The PRISMA guidelines were followed for the preparation of this paper [16].

Database search

The following electronic bibliographic databases were searched: PubMed, Embase, Scopus, Web of Science, CAB Abstract Core Collection and Google Scholar. The literature search considered studies from year 1900 to April 2020. Keyword searches were performed for “Satiation", "Satiety response", "Appetite", "Hunger", “Humans”, “Fullness”, "Prospective Food Consumption", "Desire To Eat", "Motivation To Eat" and “Satiety Quotient”. The search strategy for each of the databases are detailed in Table 1. The search strategies were developed based on an analysis of the literature and were open-ended according to the nature of each database. The reference lists of the articles included were also examined to complete the search.

Study eligibility

Inclusion criteria. To be included in the review, studies had to use SQ. There was no exclusion criterion for the study design (cross-sectional, observational, longitudinal or interventional), population (no limit for age, weight status and associated complications and both genders were included), meal type (standardized or ad libitum). Published peer-reviewed studies, conference proceedings and posters (when data and design properly described), theses and dissertations were eligible.

Exclusion criteria. When data were presented in a graphical form without mean or standard deviation (SD) indicated, the corresponding author of the work was contacted to obtain complementary data. If the corresponding author did not answer or declined the query, studies were excluded. When the full text was not found and the corresponding author was unreachable or did not respond, the article was excluded.

Study selection. Titles and abstracts of potentially relevant studies were screened in duplicate for inclusion in the review and any discrepancies were collectively discussed by the authors. The same procedure was followed for the full texts. Any disagreement regarding eligibility for inclusion was discussed and a consensus made among co-authors.

Data extraction

For every included study, the following data were extracted: sample size and characteristics (sex, age, BMI), study design and aim, VAS characteristics (specific appetite sensations assessed and timing), meal characteristics, SQ equation and main SQ results.

Risk of Bias

Risk of bias was independently evaluated by two authors (AF, DT) using the Cochrane risk of bias tool [17]. Risk of bias was assessed for: selection bias; performance bias; detection bias; attrition bias; reporting bias. Any discrepancies in bias coding were resolved by a third reviewer. Studies were not excluded on the basis of risk of bias.

Results

The flow diagram presented in Figure 1 illustrates the selection/inclusion/exclusion process. The initial database search identified 1281 studies and 9 additional studies were also identified. Following the removal of duplicate studies, 495 studies were identified. After review of titles and abstracts, 162 studies were excluded and 85 full-text were screened, leaving 52 included studies. Table 2 details the risk of bias analysis. Of the 52 studies included, 33 were acute studies [6–8,11,13–15,18–42] and 19 were longitudinal studies [9,10,12,43–59].

……………………………………………Figure 1……………………………………………

Acute studies

Of the 33 acute studies, 29 were conducted in adults [6–8,11,13–15,18–37,40,43] and 4 in adolescents [38,39,41,42].

Adult acute studies (n=29)

Main aim, population and design

The main aims, populations and used designs are presented in Table 3 and fully detailed in supplementary materials.

Methods

Topics

Of the 29 studies, 90% (n=26) compared SQ in response to a stimulus (meal, exercise, sleep), the remaining studies [8,13,14] used SQ to categorize their population (high or low satiety phenotype). Fifty-nine percent of the included studies (n=17) compared the SQ response to meals of different composition. Of these 17 studies, 2 used liquid meals [28,33], 14 solid meals

[6,14,15,18,19,21,22,25,27,30,34–37,40] and 1 study compared solid versus liquid meals [32]. Of these studies, 3 examined the effect of meals differing in energy content [14,28,33] and 5 studies compared the effect of meals differing in macronutrient composition [6,15,18,19,25]. Martini et al. [27] compared the effect of meals differing in fiber and protein, and Au-Yeung [30] compared the effect of different amounts protein intake via konjac glucomannan capsules and one study examined the combined effects of a modification in macronutrients, unsaturated fats, fiber and calcium [40]. In a slightly different way, Felix et al. [32] compared the effect of different kinds of rice and Finlayson et al. [35] the effect of different tastes on appetite sensations. Defries et al. [22] compared the different satiating effects of meals made from buckwheat flour or rice flour, while Felix et al. [36] compared the different satiating effects of white rice or brown rice using 4 different types of rice and Kendall et al. [34] the effect of different resistant starch compositions using beverages. Finally, in their study, Bligh et al. [21] investigated the satiating effect of two different types of Paleolithic meals compared to a reference meal.

Three of the studies investigated the influence of sleep on SQ [20,29,31]: one examined the effect of sleep duration [20], while another examined the timing [31] and a last one assessed the influence of the duration, quality and timing of sleep [29]. Two of the 28 studies investigated acute medication interventions [23,26] and 1 assessed the effect of hormone infusions [24]. Among the acute studies, 2 included acute exercise in their protocol and compared appetite sensations after the same exercise performed at different blood glucose levels [7] and the other compared different intensities of exercise [37] or different activity related energy expenditure [43]. One study investigated the effect of mental work [11], and another compared the appetite sensation response of men and women [8]. Finally, Drapeau et al. [13] characterized the biopsychobehavioural profiles of men with low satiety phenotype at the start of a weight loss intervention.

VAS

Regarding the type of VAS used, 79% (n=23) of acute studies used the pen and paper method [6–8,11,13,14,20,22,24,26–37,40,43], 10% (n=3) used electronic VAS [18,21,23] and 3 studies did not specify the type of scale used [15,19,25]. Of the 23 studies using pen and paper scales, 15 used 100-mm scales [6,14,20,22,24,26,27,30–36,43], while 8 used 150-mm scales [7,8,11,13,28,29,37,40]. For studies that used electronic VAS, 1 used 100-mm scales [18], one used 60-mm scales [21] and one did not specify the length of the scale used [23] . The 3 studies that did not specify the type of scale used also did not specify the length of the scale [15,19,25].

Out of the 29 studies, 28 assessed “Hunger” [6–8,11,13–15,18–26,28–37,40,43], 24 measured “Fullness” [7,8,11,13,14,18,20–31,33,34,36,37,40,43] and 20 investigated “Prospective Food Consumption” [7,8,11,13–15,18,20,22,24,28–31,33,34,36,37,40,43]. “Desire to Eat” was assessed in 20 studies [7,8,11,13–15,18,21–23,27–31,34,36,37,40,43] and “Satiety” in 4 studies [18,20,24,27]. However, as described below, all appetite sensations measured were not used for the calculation of SQ.

Calculation of SQ

Equations used

Of the 29 acute studies included, 8 used the initial equation proposed by Green et al. (1997) [6,22,24,30,33–35,43]: (appetite sensation pre-meal - appetite sensation post meal) / EI of eating episode. This equation was slightly reworked by Drapeau et al. (2007), who used this equation but multiplied the result by 100. Fifteen studies used the equation proposed by Drapeau et al. [7,8,13,14,18–20,25,28,29,31,32,36,37,40]. While previous studies have used similar equations, others have calculated the SQ slightly differently. Chapman et al. [26] calculated two SQ: a prandial SQ that considered in its calculation both pre- and post-meal appetite sensations, and a post-prandial SQ only considering post-meal sensations. In their study, Martini et al. [27] calculated three different SQ: 1) the same equation as Drapeau et al. using the pre- and post-lunch appetite sensations and energy content of lunch; 2) (appetite sensation before lunch – appetite sensation before snack) /energy content of lunch * 100; and 3) (appetite sensation before lunch – appetite sensation after snack) / (energy content of lunch + snack) * 100. More specifically, Au Yeung et al. used the Green equation for SQ_H, SQ_{DTE} and SQ_{PFC}. For SQ_F, they subtracted fullness post-eating from fullness fasting. Salama et al. [11] also reversed the order of subtraction between appetite sensations contrary to what was done by Drapeau, subtracting pre-meal sensations from post-meal sensations. Two studies did not specify the type of equation used [15,21]. Finally, Thomas et al. used an adapted version of the equation proposed by Green and calculated “satiation quotient” per quartile, reflecting the satiety capacity of a food as eaten ((quartile initial hunger – quartile ending hunger rating)/calorie consumed during quartile) [23].

Appetite sensations used

Although we have previously detailed the different appetite sensations assessed in the included studies, SQ was not calculated in each of these studies using all the assessed sensations. Twenty-five studies calculated an SQ for "Hunger" [6–8,11,13,14,19–26,28–32,34–37,40,43] , 16 for "Fullness" [7,8,11,13,20,21,24,27–29,31,34,36,37,40,43] and 15 for "Desire To Eat" [7,8,11,13,21,27–

[31,34,36,37,40,43] and "Prospective Food Consumption" [7,8,11,13,20,24,28–31,34,36,37,40,43]. Drapeau et al. also calculated a mean SQ with the SQ results corresponding to the four previous appetite sensations [13]. In 3 of the acute studies, an SQ for "Satiety" was calculated [20,24,27]. Hansen et al. [18] calculated what they named an Appetite Quotient (similar to SQ), based on composite appetite scores (with Hunger, Satiety, Fullness, Prospective Food Consumption and Desire To Eat). Gonzalez et al. [33] also produced a composite SQ, whose equation is however not detailed. In their work, Hollingworth et al. [15] did not detail in the publication which appetite sensation was used to calculate the SQ.

Timing of the sensations used

For the SQ calculation, out of the 29 studies, 23 chose to define as "pre-meal sensations" the sensations recorded immediately before the tested meal [7,8,11,13,14,18–20,22,25,27–34,36,37,40,43]. The remaining 6 studies assessed pre-lunch sensations 1 hour before the meal [26], 20 minutes before the meal [21] or 5 minutes before the meal [24]. Three studies did not specify the timing of the VAS [15,23,35]. Two studies also assessed appetite feelings during the meal [23,24]. Regarding the use of post-meal appetite sensations for calculating SQ, 8 studies evaluated them up to 60 minutes after the end of food intake [7,8,13,23,28,29,33,37], 5 studies up to 120 minutes after the end of food intake [20,27,32,34,36], 4 up to 180 minutes after the end of food intake [18,22,25,31] and 3 up to 240 minutes after the end of food intake [6,11,40]. Hopkins et al. reported appetite sensations every hour after the end of the meal until the next meal [19] while Chapman et al. assessed appetite sensations up to 5 hours after the end of the meal [26]. Green et al. measured appetite sensations up to 75 minutes after food intake [6], Schmidt et al. reported post-meal appetite sensations up to 25 minutes after the meal [24] and finally, Harrington et al. reported post-meal appetite sensations immediately after the end of the meal [43]. The study from Blight et al. reported appetite sensations up to 175 minutes after the start of food intake, while Dalton et al. reported these sensations up to 90 minutes after the start of the meal. The timing of VAS are summarized in detail in Table 3.

Type of meal

Finally, SQ was also calculated in response to different meals. Among the included acute studies, 13 used a standardized fixed meal to calculate SQ [7,8,13,21,22,28–30,32–34,36,37], while 3 used an individualized meal based on percentage of energy needs [14,31,35] and 6 used an ad libitum meal [20,23–26,43]. Six studies calculated the SQ on both types of meals: standardized and ad libitum [6,11,18,19,27,40]. One study did not specify the type of meal used to calculate the SQ [15]. Table 3 details the different meals used in the included studies.

Acute studies conducted in children and adolescents

Main aim, population and design

The main aims, populations and used designs are presented in Table 4 and fully detailed in supplementary materials.

Methods

Calculation of SQ

Three of the included studies used pen and paper VAS [38,39,42], and Kral and collaborators did not specify the type of scale used [41]. In their studies, Thivel et al. and Fillon et al. used 150-mm scales [39,42] and Albert et al. et Kral et al. used 100-mm scales [38,41]. Albert and colleagues [38] assessed “Desire To Eat ”, “Hunger”, “Fullness”, “Anticipated Food Consumption”, “Desire for specific food types”, “Palatability”, “Appreciation” and “Visual appeal”. The others assessed “Desire To Eat ”, “Hunger”, “Fullness” and “Prospective Food Consumption” [39,41,42].

Regarding the calculation of SQ, all of the included studies used the equation proposed by Drapeau et al. (2007) (appetite sensation pre-meal - appetite sensation post-meal) / EI of eating episode * 100. While Albert et al. only used the immediate post-meal sensation in the equation [38], the three other studies used a mean of post-meal sensations assessed: immediately post-meal, 30 minutes and 60 minutes post-meal in Thivel et al. et Fillon et al.’s studies [39,42], and immediately post-meal and 15 minutes post-meal in Kral et al. [41].

Although Albert et al. [38] assessed different appetite sensations, they only calculated the SQ_H while the three other studies calculated the SQ for each of the appetite sensations assessed: Desire To Eat , Hunger, Fullness and Satiety [39,41,42]. All studies calculated their SQ using an ad libitum lunch meal.

Chronic studies conducted in adults

Main aim, population and design

The main aims, populations and used designs are presented in Table 4 and fully detailed in supplementary materials.

Methods

Topics

Eighty-four percent of the included chronic studies investigated the SQ in response to lifestyle changes (e.g. changing from inactive to active) or physiological modifications (e.g. pre- vs. post-menopause in women) [9,10,44–52,54–57,59] while 3 of these 19 studies used SQ as a tool to classify the population as low and high satiety phenotype [12,53,58].

Two observational studies were included and examined the association between SQ and the change of EI, BW and body composition over time [9,10].

Among the included interventional studies, 7 assessed the effect of different dietary prescriptions on SQ [12,44–46,55,58,59] while 2 assessed the effect of different physical activity prescriptions on SQ [50,57]. One study investigated the effect of a prescription combining physical activity and dietary interventions on SQ [47]. One assessed the effect of weight change on SQ [48] and three others more specifically on the effect of different energy restrictions on SQ change [53,54,59]. Bédard and colleagues investigated the effect of sex on SQ [49] and Carbonneau et al. the effect of different nutritional labelling [52]. Finally, the effect of probiotic [51] or pharmaceutical [56] compounds on the change of SQ was also tested.

VAS

Fifteen studies used pen and paper VAS [9,10,12,45–49,51–54,56,58,59] while the other 4 used electronic VAS. Of the 15 that used the pen and paper method, 6 used 100-mm scales [45,46,54,56,58,59] while the others used 150-mm scales [9,10,12,47–49,51–53]. With regards to electronic VAS, one study used a 7-point scale [44], another used a scale ranging from -3 to 3 [55] and finally 2 studies did not specify the length of the scales used [50,57].

Sixteen of the 19 studies analyzed "Hunger" [9,10,12,45–54,56,57,59] and 15 assessed "Fullness" [9,10,12,47–54,56–59]. Thirteen studies investigated "Desire To Eat" [9,10,12,47–51,53,54,56,57,59] and 12 assessed "Prospective Food Consumption" [9,10,12,47–51,53,54,56,59]. Two studies used a single scale with "Hunger" and "Fullness" as extremes [44,55].

Calculation of SQ

Equations used

Seventy-four percent of the included studies used the following equation proposed by Drapeau et al. [10,13]: (appetite sensation pre-meal - appetite sensation post-meal) / EI of eating episode * 100 [9,10,12,45,46,48–54,57,59]. Buckland et al. used the same equation, but they subtracted post-meal sensation from pre-meal sensation, because they evaluated just “Fullness” [58]. Hintze et al. reversed also the order of subtraction between appetite sensations contrary to what was done by Drapeau, subtracting pre-meal sensations from post-meal sensations, for SQ_F [54]. Three studies used the same equation without multiplying the result by 100 [44,47,56] and one study did not clearly specify the equation used [55].

Appetite sensations used

On the 19 chronic studies, 15 calculated SQ_H [9,10,12,45–48,50–54,56,57,59], 14 SQ_F [9,10,12,44,47–49,51–56,58] and 9 SQ_{DTE} [9,10,12,47,48,51,53,54,56] and SQ_{PFC} [9,10,12,47,48,51,53,54,56] (see Table 5).

Timing of the sensations used

More specifically, all studies considered as "pre-meal appetite sensation" the sensations given immediately before the meal. With regard to "post-meal appetite sensation", 5 studies used only the sensations immediately after the meal [45,47–49,52] and 2 studies considered the post-meal sensations as the sensations recorded 30 minutes after the start of ingestion [44,55]. Others averaged appetite sensations immediately after eating with appetite sensations 1 hour after eating [57], or every 10 minutes for 1 hour [10,51,53], or every 10 minutes for 1 hour plus 90 minutes and 120 minutes after eating [12]. Three studies used the average appetite sensation immediately after eating with the sensations reported every 30 minutes for 3 hours [9,54,59] while Halford et al. [56] and Buckland et al. [58] used the same protocol but with appetite sensation evaluations every hour for 3 hours and not every 30 minutes. Finally, Golloso-Gubat and colleagues [46] used the average of appetite sensation at 15, 30, 45, 60, 90, 120, 150, 180, 240 minutes after the meal to calculate "post-meal appetite sensation". One study [50] indicated that it had integrated in the calculation of the post-meal sensations the sensations of appetite immediately after the meal as well as sensations assessed periodically between the 2 meals (Table 5).

Type of meal

Out of the 19 included studies, 7 calculated the SQ in response to a standardized fixed meal [9,10,12,46,48,51,53] while 5 used an ad libitum meal [44,45,47,52,55] with one study using both type of meals [56]. Six studies [49,50,54,57–59] calculated the SQ on an individualized meal based on a percentage of energy needs.

Main Results

By adopting a systematic overview of all the included studies, a large heterogeneity is observed when it comes to the purpose of using SQ. While all details are presented in Tables 3, 4 and 5, five main methodological uses of the SQ can be identified: i) the association between SQ and energy intake [7–9,12,15,18,19,21,22,25,27,32,36,40,44–46,49,54,55,58,59]; ii) the association between the SQ and anthropometric variables [8–11,47,48,53,59]; iii) the association between SQ and energy expenditure/physical activity [7,14,37,43,50,57]; iv) the association between SQ and sleep quality and quantity [20,29,31]; v) SQ to classify individuals into low and high satiety phenotypes [13–15,40,53,58].

The following sections presents and categorizes the main results observed in the included studies. While only the main methodological aspects and results related to the use of the SQ are details in this section, the Tables 3, 4 and 5 presents the full details of the included studies.

Association between SQ and energy and macronutrient intake

First, four of the included studies demonstrate that SQ is a predictor of food intake [7–10]. The systematic analysis of these studies shows that SQ_F [8–10], SQ_H [7], SQ_{PFC} [9] and mean SQ [9] predict EI and SQ_F predicts relative EI too (subtracting resting metabolic rate from total energy intake) [8]. A distinction is made in the studies between objectively measured EI and self-reported EI using food diaries, with SQ_{DTE}, SQ_H, SQ_F [7] and SQ_{PFC} [9] predicting reported EI only. More specifically, according to these studies, macronutrient intake could be predicted by SQ_F, SQ_{PFC} and mean SQ [9] and SQ_F could also predict CHO intake in food diaries [9]. In children, Kral et al. suggest that energy density may influence satiety responsiveness and that SQ may predict IE [41] .

Association between SQ and anthropometric variables

Five of the included studies show associations between the SQ and anthropometric or body composition variables [8,9,11,53,58,59]. Concerning BW, we observe that individuals with high satiety phenotype lost more BW than those with a low satiety phenotype [12,53,58] and we find the same conclusions regarding waist circumference in women with obesity [58]. In fact, individuals with a high waist circumference had lower satiating effect determined by the SQ_F [11] and McNeil et al. showed in their 5-year study that changes in SQ was negatively correlated with the change in waist circumference [9]. With regards to the relationship between SQ and fat mass, Salama et al. found a positive relationship between % fat mass and SQ_F [11]. In their longitudinal study, McNeil et al. found a positive correlation between the SQ and fat mass changes (delta) over the entire study, although they found a negative correlation between year 4 and year 5 [9].

Association between SQ and energy expenditure/physical activity

Three of the included studies show contradictory associations between SQ and exercise or the level of physical activity [25,43,50,57]. Some cross-sectional results suggest a decrease in SQ, indicating a lower satiety responsiveness, in lean individuals with high activity-related energy expenditure [43] while others show no effect of habitual physical activity level on SQ in non-obese individuals [25]. In individuals with overweight and obesity, a 12-week exercise intervention led to increased satiety responsiveness to a fixed meal [50,57].

With regard to studies in children, it can be observed that the timing between exercise and a meal [37,43] or the use of an energy replacement strategy [9] have no effect on SQ and that no particular association was found with SQ. However, a better satiety responsiveness (higher SQ) was observed when exercise is performed just before a meal vs. a rest condition [43].

SQ to classify individuals into low and high satiety phenotypes

Six of the included studies support the SQ as a reliable tool to phenotype individuals based on their satiety responsiveness [12–15,53,58]. Indeed, compared to individuals with a high satiety phenotype, individuals with a low satiety phenotype have higher EI, greater cravings for sweet foods, lower craving control, higher disinhibition and fasting Hunger, Desire To Eat and Prospective Food Consumption and exhibit a higher wanting for high-fat food [14,15,58].

The behavioral and psychological characteristics of the low satiety phenotype are associated with a greater susceptibility to overconsumption [14,15]. These results are also corroborated by another study, where Drapeau et al. indicate that the higher increase in cognitive restraint and a lower decrease in disinhibition in response to a weight loss intervention could increase the susceptibility of these individuals to weight gain [53], these results being in agreement with another work from Drapeau et al. showing that SQ negatively correlated with the external locus for Hunger measured by the Three-Factor Eating Questionnaire [13]. Moreover, Buckland et al. found a weaker control over eating and weight loss program adherence in people with a low satiety phenotype, as well as a lower weight loss compared with people with a high satiety phenotypes[58].

Discussion

While there has been a growing use of the SQ in clinical studies since its development by Green and colleagues in 1997 [6], little attention has been paid regarding its use since then and a high methodological heterogeneity can be observed between studies. A better understanding of the SQ and its clinical implication is of particular interest since, as shown by several studies, by including both pre-meal sensation and the energy content of the meal in its calculation, it seems to provide different information than appetite sensations alone. Indeed, some studies have observed different results for appetite sensations and SQ in response to various stimuli (such as exercise or sleep for instance) [31,37] . In that context, the present review aimed to systematically analyze the available evidence regarding the scientific and clinical use of the SQ. Fifty-two studies were included after our database search, 33 of them being cross-sectional/acute [6–8,11,13–15,18–42] and 19 being longitudinal [9,10,12,43–59]. The large majority of the included studies enrolled adults participants with only 4 enrolling children and adolescents [38,39,41,42].

According to our analysis, acute studies mainly used the SQ to compare the satiating effect of different kinds of meals varying in texture (liquid and solid) [6,14,15,18,19,21,22,25,27,28,30,32–36,40], energy content [14,28,33,41] or composition [6,15,18,19,21,25,27,30,34,36,40]. Some of these acute investigations also assessed the effect of sleep characteristics (i.e. timing, quality or duration) [20,29,31], exercise [7,37], mental work [11], gender [8] or pharmaceuticals [23,24,26] on the SQ. Regarding the interventional studies included in our analysis, they mainly used the SQ to evaluate the effect of different dietary and/or exercise interventions [12,44–47,50,51,53–55,57,59] on the SQ. Finally, some studies (acute and chronic) used the SQ to classify individuals as low or high satiety phenotypes [13–15,40,53,58].

Clinical utility and reliability of the SQ

According to the present systematic approach, the use of the SQ might be a reliable predictor of both measured [7–10,58] and reported [7,9,10] energy intake, as well as macronutrient intake [9]. Studies effectively highlight higher food consumption with lower satiety responsiveness to a meal (lower SQ) in T1D [7], healthy women [15], men and women with overweight [8], premenopausal women [9] and women with obesity [54,58]. This is reinforced by other results demonstrating negative associations between SQ and BW, waist circumference as well as fat mass [9,11,53,58]. Importantly, Drapeau et al. [53] found a positive association between SQ and weight loss in response to an energy restriction intervention in men and women with obesity, like Buckland et al. in women with obesity [58]. The SQ has been used as a clinical tool to categorize people depending on their level of satiety responsiveness to a standardized fixed meal; a low phenotype characterizing people who report difficulties in appropriately recognizing their appetite sensations before or after a meal [8]. These results are supplemented by those of Buckland et al., which have shown that people with low satiety phenotype have a weaker control over eating and weight loss program adherence compared to people with high satiety phenotype [58]. Moreover, people with low satiety phenotype prefer and consume more of high energy density food than people with high satiety phenotype [58]. While most studies use a median split to categorize low and high satiety phenotypes, in a clinical context, a low satiety phenotype might be observed in about 10% of patients with obesity who declare themselves as unable to detect changes in their appetite, report a weak satiety response to a meal and even show an increase in appetite after a meal for some of them [60]. Altogether these results suggest that the SQ is an interesting clinical indicator to identify adults at risk of overeating and thus could be used in preventive strategies and weight loss interventions. Moreover, while the literature seems to suggest the SQ and the SQ phenotype as complementary tools to already existing subjective methods (such as the evaluation of disinhibition using the TFEQ), providing additional information regarding the risk of overeating for instance, comparison studies are still missing and should be conducted.

Interestingly, while the SQ has been studied in the context of nutritional manipulations, some studies also examined its relationship and response to physical activity and exercise. According to these studies, moderate physical activity levels in lean individuals and exercise training in individuals with overweight and obesity are associated with a higher SQ, suggesting an improved satiety responsiveness [43,50,57]. However, this was not the case in studies measuring SQ at an ad libitum meal in lean individuals with very high physical activity levels, one of which showing lower SQ [43] and another showing similar SQ [25] than their less active counterparts. Using a different methodology to assess the satiety response to food (preload-test meal protocol), other studies have shown that physically active individuals have better ability to adjust subsequent energy intake following preloads differing in energy content [61,62]. These results, whether using the SQ or energy compensation following a preload as an indicator of satiety responsiveness, illustrate a relationship between physical activity, food intake and appetite control [63]. Here again, it suggests the clinical interest of the SQ as part of multidisciplinary approaches developed to prevent and treat obesity in adults.

According to our systematic approach, only few (n=4 out of 52) studies very recently used the SQ among children and adolescents. Three of them investigated the effect of acute exercise on the subsequent satiating effect of a meal [38,39,42] and the last, the effect of different preload energy density on satiety responsiveness. While two of these studies did not observe any effect of an acute exercise bout on the SQ calculated on the following ad libitum meal [38,42], Fillon et al. found increased SQ for Hunger, Prospective Food Consumption and Desire To Eat after acute moderate intensity exercise in adolescents with obesity [39]. Kral and coworkers suggested a beneficial effect of a low energy density preload on satiety responsiveness in children [41]. In addition to the lack of available evidence regarding the use of the SQ in youth, the absence of any validation study in his population must be highlighted. Indeed, it remains unknown whether the SQ is a clinically valid and reliable tool to be used in children and adolescents. Based on the increasing interest in the appetite control of children and adolescents, particularly in those with obesity, our research group recently conducted a methodological study assessing the reproducibility of SQ and its validity as an indicator of body corpulence and composition as well as of EI in adolescents with obesity [64]. Although SQ_H showed a relatively modest reproducibility, none of the other SQ variables were found reproducible and no association were found with anthropometric variables, body composition or EI [64]. This clearly calls for caution when interpreting existing results and for further studies developing reliable tools to measure the satiating effect of food in this population.

Methodological considerations

Our systematic analysis reveals a high level of heterogeneity regarding the methods used (equation used, type of meal, timing of the measurements of appetite sensations, etc.). While the SQ has been suggested as reliable and reproducible in adults, especially men with obesity (ICC for the SQ mean of 0.67) [13,14], more studies are needed to assess its validity and reproducibility in various contexts and populations.

While 43 out of the 48 adults studies included [6–14,18–20,22–37,40,43–54,56–59] used the equation initially developed by Green and colleagues [6], others used derived equations [11,23,26,27] or did not specify the equation used [15,21,55]. Similarly, as detailed in the tables and results section, the VAS used (e.g. 100 vs. 150 mm) and the timing of the measurements of appetite sensations, with some studies only using the post-meal appetite sensation while others using the mean of the appetite sensations for up to several hours post-meal, vary between studies making any comparisons difficult. Since appetite sensations are dynamic, and postprandial effects might be detected and integrated by individuals at different post-meal intervals, it would be of interest to better examine the best postprandial timing to use when calculating SQ. Importantly, while the SQ has been validated under standardized conditions and mainly using a fixed meal [8,14], 37,5% (n=18) of the included studies used an ad libitum meal to calculate the SQ [6,11,18–20,23–27,30,40,43,44,47,52,55,56]. Gonzalez and collaborators examined the accuracy of the SQ depending on the energy content of the ingested meal and observed a better reproducibility and reliability of SQ (mean SQ as well as SQ_H, SQ_F, SQ_{PFC}, SQ_S) in response to higher energy content compared to meals of lower energy content [33]. Finally, while the validity of the SQ among men [13] and women [14] was suggested, it has been widely used among specific populations such as individuals with diabetes [7,26], premenopausal women [9,28], people with different levels of physical activity [25], people with overweight and obesity [8,10,12,13,19,24,26,29,45,47,57,59], and shows a highly variable degree of correlations between studies (as detailed in tables 3 and 5). Once more, this must lead us to interpret these results with caution and calls for more methodological validations.

Conclusion

While the current systematic review suggests the reliability of the SQ in adults and encourages its use as an interesting clinical tool regarding the satiety responsiveness to a meal and its changes in responses to weight loss; we also encourage the adoption of a more standardized use of the SQ as well as the development of additional studies assessing its validity in several contexts and populations, especially among children and adolescents. Further studies should also be conducted to identify the potential biological markers associated with this SQ. Based on the present systematic analysis, we encourage future studies to assess SQ for Hunger, Fullness, Desire To Eat and Prospective Food Consumption after an overnight fast in response to a standardized fixed meal, without intense physical activity, and to consistently use a validated equation (such as the one initially proposed by Drapeau et al. [10,13]). This would allow for more reliable outcomes and better comparisons across studies.

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Conflict of Interest

The authors have no conflicts of interest to disclose. The authors have no financial relationships relevant to this article to disclose.

Authorship

AF, DT, VD and AT conceived the idea and conceptualized the review. AF and DT conducted the study selection, data extraction, and methodological quality assessment. AF drafted the initial manuscript. AF, DT, KB and VD contributed to writing the manuscript. All authors read and approved the final manuscript.

References

1. Obésité et surpoids. https://www.who.int/fr/news-room/fact-sheets/detail/obesity-and-overweight (accessed March 2019).

2. Blundell JE, Gibbons C, Caudwell P, et al. (2015) Appetite control and energy balance: impact of exercise. *Obes. Rev.* **16**, 67–76.

3. Hopkins M, Duarte C, Beaulieu K, et al. (2019) Activity energy expenditure is an independent predictor of energy intake in humans. *Int. J. Obes. 2005*.

4. Harris RBS (editor) (2017) *Appetite and Food Intake: Central Control*. 2nd ed. Boca Raton (FL): CRC Press/Taylor & Francis.

5. Blundell J & Finlayson G Mechanisms and biomarkers of appetite control. In *Food Texture Food Intake Role Oral Sens. Expo.*, vol. 19(5 Suppl.), Agro Food Industry Hi-Tech, pp. 18–20.

6. Green SM, Delargy HJ, Joanes D, et al. (1997) A satiety quotient: a formulation to assess the satiating effect of food. *Appetite* **29**, 291–304.

7. Dubé M-C, Tremblay A, Lavoie C, et al. (2013) Effect of exercise on food consumption and appetite sensations in subjects with diabetes. *Appetite* **71**, 403–410.

8. Drapeau V, Blundell J, Therrien F, et al. (2005) Appetite sensations as a marker of overall intake. *Br. J. Nutr.* **93**, 273–280.

9. McNeil J, Prud’homme D, Strychar I, et al. (2014) Satiety quotient linked to food intake and changes in anthropometry during menopause: a MONET Study. *Climacteric J. Int. Menopause Soc.* **17**, 449–455.

10. Drapeau V, King N, Hetherington M, et al. (2007) Appetite sensations and satiety quotient: predictors of energy intake and weight loss. *Appetite* **48**, 159–166.

11. Salama M, Drapeau V, Tremblay A, et al. (2016) The impact of a mental work on food preferences, eating behavior traits and satiety efficiency. *Physiol. Behav.* **154**, 191–195.

12. Arguin H, Tremblay A, Blundell JE, et al. (2017) Impact of a non-restrictive satiating diet on anthropometrics, satiety responsiveness and eating behaviour traits in obese men displaying a high or a low satiety phenotype. *Br. J. Nutr.* **118**, 750–760.

13. Drapeau V, Blundell J, Gallant AR, et al. (2013) Behavioural and metabolic characterisation of the low satiety phenotype. *Appetite* **70**, 67–72.

14. Dalton M, Hollingworth S, Blundell J, et al. (2015) Weak Satiety Responsiveness Is a Reliable Trait Associated with Hedonic Risk Factors for Overeating among Women. *Nutrients* **7**, 7421–7436.

15. Hollingworth S, Dalton M, Blundell J, et al. (2018) Evaluation of the influence of different snack foods on appetite control in the low satiety phenotype. *Appetite* **123**, 458.

16. Liberati A, Altman DG, Tetzlaff J, et al. (2009) The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *J. Clin. Epidemiol.* **62**, e1–e34.

17. Higgins J & Green S (2008) *Cochrane handbook for systematic reviews of interventions.* .

18. Hansen TT, Sjodin A, Ritz C, et al. (2018) Macronutrient manipulations of cheese resulted in lower energy content without compromising its satiating capacity. *J Nutr Sci* **7**, e7.

19. Hopkins M, Gibbons C, Caudwell P, et al. (2016) Differing effects of high-fat or high-carbohydrate meals on food hedonics in overweight and obese individuals. *Br J Nutr* **115**, 1875–84.

20. Polugrudov A, Popov S, Smirnov V, et al. (2017) Association of social jetlag experienced by young northerners with their appetite after having breakfast. *Biol. Rhythm Res.* **48**, 917–929.

21. Bligh HF, Godsland IF, Frost G, et al. (2015) Plant-rich mixed meals based on Palaeolithic diet principles have a dramatic impact on incretin, peptide YY and satiety response, but show little effect on glucose and insulin homeostasis: an acute-effects randomised study. *Br J Nutr* **113**, 574–84.

22. Defries DM, Petkau JC, Gregor T, et al. (2017) A randomized, controlled, crossover study of appetite-related sensations after consuming snacks made from buckwheat. *Appl. Physiol. Nutr. Metab.* **43**, 194–202.

23. Thomas JM, Dourish CT, Tomlinson JW, et al. (2014) Effects of the 5-HT2C receptor agonist meta- chlorophenylpiperazine on appetite, food intake and emotional processing in healthy volunteers. *Psychopharmacology (Berl.)* **231**, 2449–2459.

24. Schmidt JB, Gregersen NT, Pedersen SD, et al. (2014) Effects of PYY3-36 and GLP-1 on energy intake, energy expenditure, and appetite in overweight men. *Am. J. Physiol. - Endocrinol. Metab.* **306**, E1248–E1256.

25. Beaulieu K, Hopkins M, Blundell J, et al. (2017) Impact of physical activity level and dietary fat content on passive overconsumption of energy in non-obese adults. *Int. J. Behav. Nutr. Phys. Act.* **14**, 14.

26. Chapman I, Parker B, Doran S, et al. (2005) Effect of pramlintide on satiety and food intake in obese subjects and subjects with type 2 diabetes. *Diabetologia* **48**, 838–848.

27. Martini D, Brusamolino A, Del Bo C, et al. (2018) Effect of fiber and protein-enriched pasta formulations on satiety-related sensations and afternoon snacking in Italian healthy female subjects. *Physiol. Behav.* **185**, 61–69.

28. Blanchet R, Lemieux S, Couture P, et al. (2011) Effects of neuromedin-β on caloric compensation, eating behaviours and habitual food intake. *Appetite* **57**, 21–27.

29. McNeil J, Drapeau V, Gallant AR, et al. (2013) Short sleep duration is associated with a lower mean satiety quotient in overweight and obese men. *Eur. J. Clin. Nutr.* **67**, 1328–1330.

30. Au-Yeung F, Jovanovski E, Jenkins AL, et al. (2018) The effects of gelled konjac glucomannan fibre on appetite and energy intake in healthy individuals: a randomised cross-over trial. *Br. J. Nutr.* **119**, 109–116.

31. McNeil J, Forest G, Hintze LJ, et al. (2017) The effects of partial sleep restriction and altered sleep timing on appetite and food reward. *Appetite* **109**, 48–56.

32. Felix AD, Trinidad TP, Tuano APP, et al. (2013) Short-Term Satiety of Cooked Philippine Rices of Varying Apparent Amy lose Content and Glycemic Index. *Philipp. Agric. Sci.* **96**, 179–186.

33. Gonzalez JT, Frampton J & Deighton K (2017) Postprandial suppression of appetite is more reproducible at a group than an individual level: Implications for assessing inter-individual variability. *Appetite* **108**, 375–382.

34. Kendall CW, Esfahani A, Sanders LM, et al. (2010) The effect of a pre-load meal containing resistant starch on spontaneousfood intake and glucose and insulin responses. *J. Food Technol.* **8**, 67–73.

35. Finlayson G, Bordes I, Griffioen-Roose S, et al. (2011) Susceptibility to Overeating Affects the Impact of Savory or Sweet Drinks on Satiation, Reward, and Food Intake in Nonobese Women–3. *J. Nutr.* **142**, 125–130.

36. Felix AD, Tuano APP, Mallillin AC, et al. (2016) Short-term Satiety of Brown Rice and Milled Rice. *Philipp. J. Crop Sci.* **41**, 52–59.

37. Thivel D, Fillon A, Genin PM, et al. (2020) Satiety Responsiveness but not Food Reward is modified in response to an acute bout of low versus high intensity exercise in healthy adults. *Appetite* **145**, 104500.

38. Albert M-H, Drapeau V & Mathieu M-E (2015) Timing of moderate-to-vigorous exercise and its impact on subsequent energy intake in young males. *Physiol. Behav.* **151**, 557–562.

39. Fillon A, Mathieu M-E, Masurier J, et al. (2020) Effect of exercise-meal timing on energy intake, appetite and food reward in adolescents with obesity: the TIMEX study. *Appetite* **146**, 104506.

40. Arguin H, Gagnon-Sweeney M, Pigeon É, et al. (2012) Functional food and satiety. Impact of a satiating context effect on appetite control of non-obese men. *Appetite* **58**, 354–363.

41. Kral TVE, Moore RH, Chittams J, et al. (2020) Caloric compensation and appetite control in children of different weight status and predisposition to obesity. *Appetite* **36**, 42–55.

42. Thivel D, Roche J, Miguet M, et al. (2020) Post-moderate-intensity exercise energy replacement does not reduce subsequent appetite and energy intake in adolescents with obesity. *Br. J. Nutr.* **123**, 592–600.

43. Harrington DM, Martin CK, Ravussin E, et al. (2013) Activity related energy expenditure, appetite and energy intake. Potential implications for weight management. *Appetite* **67**, 1–7.

44. Jönsson T, Granfeldt Y, Erlanson-Albertsson C, et al. (2010) A paleolithic diet is more satiating per calorie than a mediterranean-like diet in individuals with ischemic heart disease. *Nutr. Metab.* **7**, 85.

45. Rodríguez-Rodríguez E, Aparicio A, Bermejo LM, et al. (2009) Changes in the sensation of hunger and well-being before and after meals in overweight/obese women following two types of hypoenergetic diet. *Public Health Nutr.* **12**, 44–50.

46. Golloso-Gubat MJ, Magtibay EVJ, Nacis JS, et al. (2016) Differences in Satiating Effects of White Rice and Brown Rice in Selected Filipino Adults. *Philipp. J. Crop Sci.* **41**, 55–60.

47. Chaput JP, Pelletier C, Despres JP, et al. (2007) Metabolic and behavioral vulnerability related to weight regain in reduced-obese men might be prevented by an adequate diet-exercise intervention. *Appetite* **49**, 691–695.

48. Gilbert JA, Drapeau V, Astrup A, et al. (2009) Relationship between diet-induced changes in body fat and appetite sensations in women. *Appetite* **52**, 809–812.

49. Bédard A, Hudon A-M, Drapeau V, et al. (2015) Gender differences in the appetite response to a satiating diet. *J. Obes.* **2015**.

50. King NA, Caudwell PP, Hopkins M, et al. (2009) Dual-process action of exercise on appetite control: increase in orexigenic drive but improvement in meal-induced satiety. *Am. J. Clin. Nutr.* **90**, 921–927.

51. Sanchez M, Darimont C, Panahi S, et al. (2017) Effects of a Diet-Based Weight-Reducing Program with Probiotic Supplementation on Satiety Efficiency, Eating Behaviour Traits, and Psychosocial Behaviours in Obese Individuals. *Nutrients* **9**.

52. Carbonneau E, Perron J, Drapeau V, et al. (2015) Impact of nutritional labelling on 10-d energy intake, appetite perceptions and attitudes towards food. *Br. J. Nutr.* **114**, 2138–2147.

53. Drapeau V, Jacob R, Panahi S, et al. (2019) Effect of Energy Restriction on Eating Behavior Traits and Psychobehavioral Factors in the Low Satiety Phenotype. *Nutrients* **11**.

54. Hintze LJ, Goldfield G, Seguin R, et al. (2019) The rate of weight loss does not affect resting energy expenditure and appetite sensations differently in women living with overweight and obesity. *Physiol. Behav.* **199**, 314–321.

55. Jönsson T, Granfeldt Y, Lindeberg S, et al. (2013) Subjective satiety and other experiences of a Paleolithic diet compared to a diabetes diet in patients with type 2 diabetes. *Nutr. J.* **12**, 105.

56. Halford J, Boyland E, Cooper S, et al. (2010) The effects of sibutramine on the microstructure of eating behaviour and energy expenditure in obese women. *J. Psychopharmacol. (Oxf.)* **24**, 99–109.

57. Caudwell P, Gibbons C, Hopkins M, et al. (2013) No sex difference in body fat in response to supervised and measured exercise. *Med Sci Sports Exerc* **45**, 351–8.

58. Buckland NJ, Camidge D, Croden F, et al. (2019) Women with a low-satiety phenotype show impaired appetite control and greater resistance to weight loss. *Br. J. Nutr.* **122**, 951–959.

59. Beaulieu K, Casanova N, Oustric P, et al. (2020) Matched Weight Loss Through Intermittent or Continuous Energy Restriction Does Not Lead To Compensatory Increases in Appetite and Eating Behavior in a Randomized Controlled Trial in Women with Overweight and Obesity. *J. Nutr.* **150**, 623–633.

60. Drapeau V, Hetherington M & Tremblay A (2011) Impact of Eating and Lifestyle Behaviors on Body Weight: Beyond Energy Value. In *Handb. Behav. Food Nutr.*, pp. 693–706 [Preedy VR, Watson RR, Martin CR, editors]. New York, NY: Springer New York.

61. Beaulieu K, Hopkins M, Blundell J, et al. (2016) Does Habitual Physical Activity Increase the Sensitivity of the Appetite Control System? A Systematic Review. *Sports Med. Auckl. NZ* **46**, 1897–1919.

62. Beaulieu K, Hopkins M, Long C, et al. (2017) High Habitual Physical Activity Improves Acute Energy Compensation in Nonobese Adults: *Med. Sci. Sports Exerc.* **49**, 2268–2275.

63. Beaulieu K, Hopkins M, Blundell J, et al. (2018) Homeostatic and non-homeostatic appetite control along the spectrum of physical activity levels: An updated perspective. *Physiol. Behav.* **192**, 23–29.

64. Fillon A, Masurier J, Pereira B, et al. (in press) Usefulness of Satiety Quotient in a clinical pediatric obesity context. .

Figure Legends

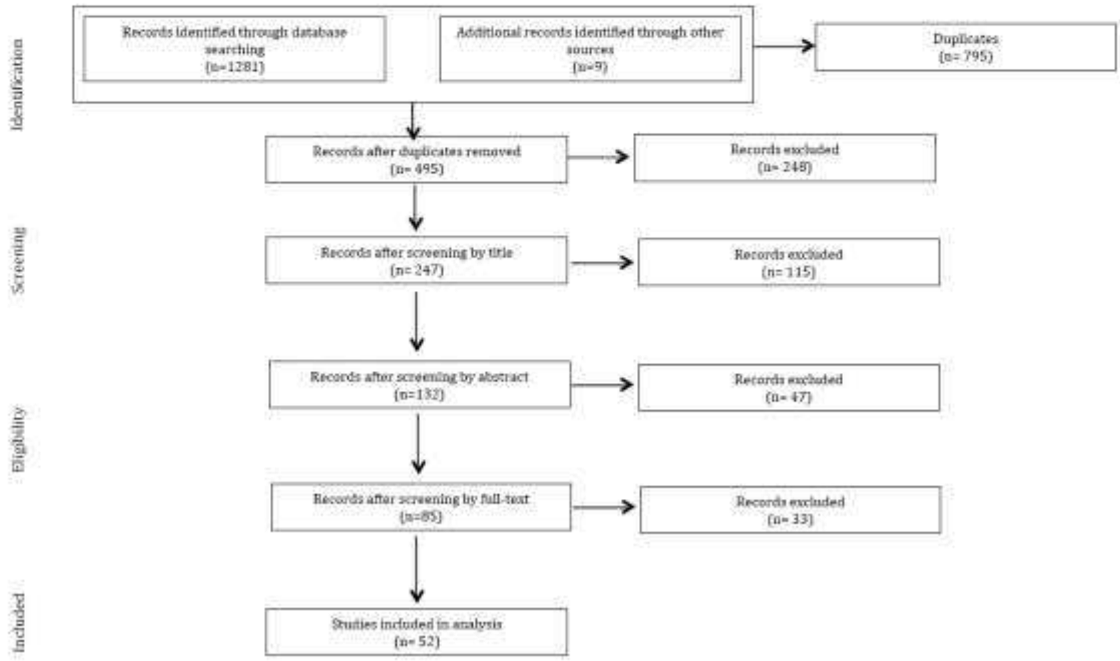

Table 1: Database search strategy details

Data Base	Equation	Filters
Pubmed	((((((((("Satiation"[Majr]) OR "Satiety Response"[Majr]) OR "Appetite"[Majr:NoExp]) OR "Hunger"[Majr:NoExp]) AND Humans[Mesh])) OR (((satiety[Title/Abstract] OR satiation*[Title/Abstract] OR appetite[Title/Abstract] OR fullness[Title/Abstract] OR hunger[Title/Abstract] OR "Prospective food consumption"[Title/Abstract] OR "desire to eat"[Title/Abstract] OR "motivation to eat"[Title/Abstract])) AND Humans[Mesh])) AND Humans[Mesh])) AND quotient[Title/Abstract]	Humans
Embase	(*satiety OR *satiety response OR *appetite OR *hunger OR fullness.mp OR "desire to eat".mp OR "Prospective food consumption".mp OR "motivation to eat".mp OR satiety.mp. OR satiation*.mp. OR hunger.mp. OR appetite.mp. AND (quotient.mp.	Humans
Scopus	(TITLE-ABS-KEY (satiety OR satiation OR appetite OR fullness OR hunger OR "Prospective food consumption" OR "desire to eat" OR "motivation to eat") AND TITLE-ABS-KEY (quotient))	Humans
Web of Science	((Satiety OR satiation OR appetite OR fullness OR hunger OR "Prospective food consumption" OR "desire to eat" OR "motivation to eat") AND (quotient))	Humans
CAB Abstract Core Collection	((Satiety OR satiation OR appetite OR fullness OR hunger OR "Prospective food consumption" OR "desire to eat" OR "motivation to eat") OR ("hunger" OR "satiety" OR "appetite")) AND (Quotient)	Humans
Google Scholar	« Satiety Quotient »	

Mp = title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word

Table 2: Risk of bias

Study	Random Sequence Generation (Selection bias)	Allocation concealment (Selection bias)	Blinding participants and personnel (Performance bias)	Blinding of outcome assessment (Detection bias)	Incomplete outcome data (Attrition bias)	Selective reporting (Reporting bias)
Albert et al., 2015 [38]	L	NR	L	M	L	L
Arguin et al., 2012 [40]	H	NR	NR	M	NR	L
Arguin et al., 2017 [12]	L	NR	NR	M	M	L
Au-Yeung et al., 2018 [30]	L	NR	NR	M	NR	L
Beaulieu et al., 2017 [25]	L	NR	NR	M	H	L
Beaulieu et al., 2020 [59]	L	NR	M	M	M	L
Bédard et al., 2015 [49]	H	NR	NR	M	L	L
Blanchet et al., 2011 [28]	L	NR	L	L	NR	L
Bligh et al., 2015 [21]	L	NR	L	M	H	L
Buckland et al., 2019 [58]	L	L	NR	M	L	L
Carbonneau et al., 2015 [52]	L	NR	NR	M	NR	L
Caudwell et al., 2013 [57]	H	NR	NR	M	L	NR
Chapman et al., 2005 [26]	L	L	L	M	L	NR
Chaput et al., 2007 [47]	H	NR	NR	M	L	L
Dalton et al., 2015 [14]	L	NR	NR	M	NR	L
Defries et al., 2017 [22]	L	NR	NR	H	NR	L
Drapeau et al., 2005 [8]	H	NR	L	M	NR	L

Drapeau et al., 2007 (10)	H	NR	M	M	L	L
Drapeau et al., 2013 (13)	H	NR	NR	L	H	NR
Drapeau et al., 2019 (53)	H	NR	NR	M	H	L
Dubé et al., 2013 (7)	L	NR	NR	M	NR	L
Felix et al., 2013 (32)	L	NR	NR	M	NR	NR
Felix et al., 2016 (36)	L	NR	NR	M	NR	NR
Fillon et al., 2020 (39)	L	NR	NR	M	L	L
Finlayson et al., 2011 (35)	L	NR	M	M	M	L
Gilbert et al., 2009 (48)	H	NR	M	M	L	L
Golloso-Gubat et al., 2016 (46)	L	NR	NR	M	L	NR
Gonzalez et al., 2017 (33)	M	NR	NR	M	NR	NR
Green et al., 1997 (6)	H	NR	NR	M	NR	NR
Halford et al., 2010 (56)	M	L	L	M	M	L
Hansen et al., 2018 (18)	L	NR	M	M	NR	L
Harrington et al., 2013 (43)	H	NR	NR	M	L	NR
Hintze et al., 2019 (54)	L	NR	NR	M	H	L
Hollingworth et al., 2018 (15)	L	NR	NR	NR	NR	NR
Hopkins et al., 2016 (19)	L	NR	NR	M	NR	NR
Jönsson et al., 2010 (44)	L	NR	NR	H	H	NR
Jönsson et al., 2013 (55)	L	NR	NR	H	L	L
Kral et al., 2020 (41)	L	L	M	L	L	L
Kendall et al., 2010 (34)	L	L	L	M	M	NR
King et al., 2009 (50)	H	NR	NR	M	L	NR

Martini et al., 2018 (27)	L	NR	NR	M	H	L
McNeil et al., 2013 (29)	H	NR	NR	M	NR	L
McNeil et al., 2014 (9)	H	NR	NR	H	H	L
McNeil et al., 2017 (31)	L	NR	NR	L	M	L
Polugrudov et al., 2017 (20)	L	NR	NR	M	NR	L
Rodriguez-Rodriguez et al., 2008 (45)	L	NR	H	H	L	NR
Salama et al., 2016 (11)	L	NR	L	M	H	L
Sanchez et al., 2017 (51)	L	L	L	M	H	NR
Schmidt et al., 2014 (24)	L	L	L	M	NR	NR
Thivel et al., 2019 (37)	L	NR	NR	M	NR	L
Thivel et al., 2020 (42)	L	NR	NR	M	L	L
Thomas et al., 2014 (23)	L	NR	L	M	M	L

L: Low risk, M: Medium risk, H: High risk; NR: Not Reported

Table 3: Population, design, methods and main results of adult acute studies

Study	Population characteristics	Design	VAS timing	SQ equation	Main results
Green et al., 1997 [6] Study 1	n =18 lean, healthy, dietary unrestrained men Age= NR BMI= NR	Cross-over study Protocol: Standardized lunch, ad libitum snack 4 lunch conditions: - Low energy lunch (2238 kJ)/high CHO snack - Low energy lunch (2238 kJ)/high fat snack - High energy lunch (3962 kJ)/ high CHO snack - High energy lunch (3962 kJ)/high fat snack	Pre-lunch, post-lunch, 13:30, 14:00, 14:30, 15:00	SQ_H (mm/kJ) = (rating pre-eating standardized lunch - rating post-standardized lunch)/ energy content of standardized lunch SQ calculated for each of the 5 post-lunch time points, subtracting the ≠ ratings from pre-meal rating	**SQ, energy intake and appetite control**: - No difference between conditions. - Effect of time ($p<0\cdot001$) indicating that the lunches become less satiating per unit energy as time post-lunch ↑.
Green et al., 1997 [6] Study 2	n=20 (20 lean, healthy women, 10 dietary restrained,10 dietary unrestrained) Age= NR BMI= NR	Cross-over study Protocol: Standardized lunch, ad libitum snack, 4 conditions: - Low energy lunch (2238 kJ men, 1679 kJ women)/high CHO snack - Low energy lunch (2238 kJ	Pre-lunch, post-lunch, 13:30, 14:00, 14:30, 15:00	Same SQ equation as Study 1 SQ calculated for each of the 5 post-meal time points, subtracting the ≠ ratings from pre-meal rating	**SQ, energy intake and appetite control**: Unrestrained females: Similar SQ between conditions, a main effect of time only ($p<0.001$). Restrained females: SQ effect of time ($p<0.001$) and effect of condition ($p<0.05$).

		men, 1679 kJ women)/high fat snack - High energy lunch (3965 kJ men, 2971 kJ women)/ high CHO snack - High energy lunch (3965 kJ men, 2971 kJ women)/high fat snack			
Green et al., 1997 [(6)] **Study 3**	n =17 lean, healthy men Age= NR BMI= NR	Cross-over study Protocol: Standardized preload, ad libitum meal 3 preload conditions: - High energy high-CHO (3347 kJ) - High energy high fat (3343 kJ) - Low energy high-CHO (1828 kJ)	Pre-preload, post-preload, 15:30, 16:00,16:30, 17:00	Same SQ equation as Study 1 but for standardized preload SQ calculated for each of the 5 post-meal time points, subtracting the ≠ ratings from pre-meal rating	**SQ, energy intake and appetite control**: - Time by condition interaction ($p<0.001$) (the low-energy/high-CHO SQ was higher when preload immediately following consumption but lower than the two other conditions at 17.00 h.) - Effect of time ($p<0.001$).
Green et al., 1997 [(6)] **Study 4**	n =16 lean, healthy men Age= NR BMI= NR	Cross-over study Protocol: Standardized preload (yoghurt), ad libitum meal 4 preload conditions: - Low energy with aspartame	Pre-preload, 10, 20, 30, 40, 50, 60 min post-preload	Same SQ equation as Study 1 but for standardized preload SQ calculated for each	**SQ, energy intake and appetite control**: - SQ was higher with lower energy preloads initially than the higher energy preloads, but this effect was reversed 60 min post preload. - Effect of time ($p<0.001$)

		(506 kJ) - Low energy without aspartame (506 kJ) - High energy with sucrose (1247 kJ) - High energy with maltodextrin (1167 kJ)		of the 6 post-meal time points, subtracting the ≠ ratings from pre-meal rating	
Green et al., 1997 [6] **Study 5**	n =10 men, 9 women Age= NR BMI= NR	Cross-over study Protocol: Standardized BF, ad libitum lunch 4 ad libitum lunch conditions: - Low fat and sweet - Low fat and no sweet - High fat and sweet - High fat and no sweet	Pre-lunch, post-lunch, 30, 45, 60, 120, 180 and 240 min post-lunch	Same SQ equation as Study 1 but for ad libitum lunch SQ calculated for each of the 7 post-meal time points, subtracting the ≠ ratings from pre-meal rating	**SQ, energy intake and appetite control:** - Macronutrient by time interaction ($p<0.001$) (SQ was initially lower for high fat food than high CHO foods but after the first hour there was little difference between macronutrient types in their effects on SQ). - Main effects of condition up to an hour post-lunch ($p=0.01$).
Chapman et al., 2005 [26]	T2D: n=11 men Age=60.2±8.5 yr BMI=28.9±4.8 kg/m²	Randomized, double-blind, placebo-controlled cross-over study Protocol: Drug/placebo injection, standardized preload	1h before, immediately before and after the ad libitum lunch, and 5h	1. Prandial SQ_H = [rating 1h before ad libitum lunch - rating immediately after] / EI at the ad libitum lunch.	**Other:** - Prandial SQ: Pramlintide > placebo (by 26% in the T2D group ($p=0.21$) and by 58% in the obese without diabetes group ($p=0.03$))

	Obese without diabetes: n=15 men, Age=41±21yr BMI= 34.4±4.5 kg/m²	meal (189kcal), ad libitum buffet lunch 2 conditions per group: - Pramlintide - Placebo	after the beginning of the ad libitum lunch	2. Postprandial SQ_H = [rating 5h after ad libitum lunch – rating immediately after] / EI at the ad libitum lunch.	- Postprandial SQ: Pramlintide < placebo (by 100% in the T2D group (p=0.03) and by 120% in the obese without diabetes group (p=0.07))
Drapeau et al., 2005 [(8)]	Men: n=28 Age= 37.4±7.4 yr BMI=27.9±5.3 kg/m² Women: n=23 Age= 38.2±7.2 yr BMI= 27.4±5.3 kg/m²	Observational study Protocol: Standardized BF (733 kcal men, 599 kcal women), ad libitum lunch and dinner, TFEQ, body composition, metabolic rate 2 groups: 1. Men 2. Women	Before and immediately after BF, and every 10 min for a 1-h period after BF	SQ_H, SQ_F, SQ_{DTE}, SQ_{PFC} (mm/kcal) = [fasting rating-60 min post- BF]/energy content of BF *100.	- SQ men = SQ women. **SQ, energy intake and appetite control**: - SQ_F correlated with total EI (r= -0.42, p<0.001) (strength of the associations decreased if adjustment for BW and BMI) - SQ_F correlated with fullness 1h AUC (men+women: r=0.55, men: r=0.72, women: r=0.40, p<0.0001). - SQ_F not related with any TFEQ score. - In women, SQ_F correlated with % fat intake (r= -0.60, p=0.002). **SQ and anthropometrics variables**: - No consistent correlation between SQ and BW, BMI, percentage body fat and metabolic rate (for the whole sample or for each sex separately).

					- In women, BW correlated with SQ_{DTE} (r= -0.46, p=0.03) and SQ_{PFC} (r= -0.49, p=0.02). - In women, BMI correlated with SQ_{PFC} (r= -0.49, p=0.02). - In men, BMI correlated with SQ_{S} (r= 0.44, p=0.02). **<u>Other</u>:** - Metabolic rate correlated with SQ_{DTE} (r= -0.64, p=0.002) and SQ_{PFC} (r= -0.69, p=0.0005).
Kendall et al., 2010 [34]	n =22 healthy subjects (13 men, 9 women) Age=26±4 yr BMI=23.7±2.4 kg/m²	Randomized cross-over controlled study <u>Protocol</u>: Standardized cereal bar and beverage snack varying in dose of resistant starch (RS), ad libitum lunch 5 beverage conditions: - 0g RS (control) - 0g RS (control) - 5g RS	Before and at 15, 30, 45, 60, 90 120 min after consuming snack	SQ_H, SQ_F, SQ_{DTE}, SQ_{PFC} (mm/kcal) = (rating pre-snack - rating post-snack)/energy content of snack	**<u>Other</u>:** - SQ_F 5g RS > SQ_F control 60-min after the test meal (p<0.04). - For overall appetite score at 15, 30 and 45: SQ 25g RS meal>control (p=0.1, 0.08 and 0.04, respectively). - 25g RS meal: the average appetite SQ over the 2 h post meal time period was greater than control although this only approached significance (p=0.14)

		- 10g RS - 25g RS			
Blanchet et al., 2011 [28]	n = 153 premenopausal women P73T genotype (mutation in neuromedin-β gene): n=61 Age= 33.4±9.9yr BMI= 23.1±2.5 kg/m² P73P genotype (without mutation): n=85 Age=33.3±10.4 yr BMI= 22.7±2.7 kg/m² T73T genotype	Randomized single-blind cross-over design Protocol: Standardized dinner (day before), standardized BF, milkshake preloads at 10:00, ad libitum cold buffet 2 milkshake conditions per group: - Low energy (261 Kcal) - High energy (625 Kcal)	Before and immediately, 30 and 60 min after BF, before and immediately, 10, 20, 30, 40, 50, 60 min after milkshake and after buffet meal.	SQ_H, SQ_F, SQ_{DTE}, SQ_{PFC} (mm/kcal) = [fasting rating -mean post-meal rating]/energy content of meal*100. SQ calculated for standardized BF and preloads.	**Other:** - No effect of genotype, meal (BF or preload) or interaction, for any of SQ.

	(with mutation): n=7 Age= 30.1±9.5yr BMI= 22.5±1.2 kg/m²				
Finlayson et al., 2011 [35]	n = 30 healthy women, Age=21.9±0,5 yr BMI=22.7±0.4 kg/m²	Randomized cross-over study Protocol: Individualized preload (10% of the estimated daily energy requirement ; ~710-1050 kJ), ad libitum lunch (30 min after), 3 preload conditions: - Sweet taste - Savory taste - Bland taste	NR	SQ_H (mm/kcal) = [rating pre-preload - rating post-preload] energy content of preload	**SQ, energy intake and appetite control:** - Preloads on SQ scores: increase in satiation after consumption followed by a partial return to baseline (p<0.01). - No difference in SQ according to preload taste. - Effect of disinhibition on SQ of the preloads (p<0.05) and a disinhibition by time interaction (p<0.05). - Higher disinhibition scores associated with weaker satiation and a more rapid return to baseline SQ levels compared to lower scores.

Arguin et al., 2012 [40]	n = 18 men, Age= 31.0±10.4 yr BMI= 23.8 ± 2.9 kg/m²	Controlled study Protocol: Standardized BF (733 Kcal), ad libitum lunch 3 lunch conditions: - Control: Ad libitum control macaroni + chocolate cake - Satiating: Ad libitum macaroni containing more proteins, unsaturated fats, fibers and calcium than the control macaroni despite similar energy density, appearance and palatability + chocolate cake - Context effect: Ad libitum control macaroni but participants believed they were eating ‘‘a highly satiating macaroni”+ chocolate cake’	Before and at 0, 10, 20, 30, 40, 50, 60 min after BF, immediately before and after lunch, immediately before and after the dessert and 10, 20, 30, 40, 50, 60, 120, 180 and 240 min later	SQ_H, SQ_F, SQ_{DTE}, SQ_{PFC} (mm/kcal) =(fasting rating - mean of the 60-min post-BF ratings)/ energy content of BF)*100 SQ_{-25min}(mm/kcal) =(pre-lunch rating – rating immediately after macaroni)/EI at lunch*100 $SQ_{0-240min}$(mm/kcal) =(pre-lunch rating - rating 0-240 min after lunch)/ EI at the meal (macaroni + dessert)*100	**SQ, energy intake and appetite control:** - No condition difference for $SQ_{-25\ min}$ DTE, H, S and PFC - SQ_{DTE_0-240} and SQ_{H_0-240}, $SQ_{S\_120-240}$, SQ_{PFC_20-240}: context effect meal > control and the satiating meals ($p<0.05$). - At baseline, the SQ of the context effect meal was significantly greater from 120 to 240 min in the low satiety signals group (all AS), and at 120 and 240 min in the high satiety signals group (hunger only) (all $p<0.05$). - Dietary restraint subgroups SQ (mean $SQ_{\_25min}$) of the context effect macaroni > SQ of the control macaroni for the high restrained individuals (significant interaction between test meals and level of dietary restraint; $p=0.03$). - High restrained individuals SQ ($SQ_{0-240min}$) of the context effect meal > SQ control and the satiating meal (SQ_{DTE_0-240}, SQ_{H_0-240}, SQ_{PFC_0-240} and $SQ_{S\_120-240}$) (all $p\leq0.05$). - Low restrained individuals SQ: context

					effect meal > SQ satiating meal (SQ_{PFC_180}, SQ_{H_240}, SQ_{PFC_240}) (all $p<0.05$)
Drapeau et al., 2013 [13]	n=69 men Age=41.4±5.7 yr BMI=33.6±3.0 kg/m²	Observational study Protocol: Standardized BF (733 kcal), TFEQ, body composition 2 experimental visits: - Baseline - 2-4 weeks after	Before, immediately after, and every 10 min for a 1-h period after BF. The two last VAS were performed 90 and 120 min after the BF.	SQ_H, SQ_F, SQ_{DTE}, SQ_{PFC} and mean SQ (mm/kcal) = (fasting rating - mean of the 60 min post-BF ratings)/energy content of BF*100 Low satiety phenotype (LSP): mean SQ<8mm/100 kcal High satiety phenotype: mean SQ≥8mm/100 kcal	- Individual SQ ICC r=0.5-0.6 and mean SQ r=0.7 **SQ, energy intake and appetite control:** - Adjusted on BMI: Mean SQ tended to be correlated with TFEQ external locus for hunger (r= -0.23, p=0.06), anxiety scores (present state r= -0.21, p=0.09) and night eating symptoms scores (r= -0.22, p=0.07). - All SQ, attention to self-regulation, external locus for hunger and night eating symptoms were correlated with the SQ_{DTE} (r=0.27, 0.28 and 0.28, respectively, p<0.05). **SQ and satiety phenotype:**

					- Lower individual SQ and mean SQ ($p<0.0001$) and weaker changes in AS responses to the test-meal ($p<0.0001$) in LSP. **<u>Other</u>:** - A model including present state anxiety and external hunger was borderline significant ($p=0.08$) but explained just 28% of the variability in SQ. - Present state anxiety was related to SQ_{PFC} ($r= -0.26$, $p<0.05$). - Overall blunted cortisol response to the test-meal ($p<0.05$), which persisted after controlling for waist circumference ($p=0.04$) in LSP.
Dubé et al., 2013 [(7)]	n=16, <u>With T1D</u>: n=12 (6 men, 6 women) Age= 39.4±6.6 yr BMI=24.0±1.4 kg/m²	Randomized cross-over controlled study <u>Protocol</u>: Standardized BF (700 kcal men, 600 kcal women), exercise/rest, ad libitum lunch, self-reported 3-day energy intake (1-2 weeks before exercise)	Before, immediately after, and every 10 min for a 1-h period after BF	SQ_H, SQ_F, SQ_{DTE}, SQ_{PFC} (mm/kcal) = (fasting rating -mean 60-min post-BF ratings) / (energy content of BF) * 100	- Corrected for body weight, SQ T1D = SQ T2D **<u>SQ, energy intake and appetite control</u>:** - Correlation between SQ_H and ad libitum EI ($r= -0.33$, $p\leq0.05$) in T1D - Correlations between SQ_{DTE}, SQ_H, SQ_F and reported EI in T1D ($r= -0.43, -0.50, -0.36$ and $p\leq0.01, 0.01, 0.05$, respectively)

	With T2D: n=4 (3 men, 1 women) Age= 53.3±2.8 yr BMI=25.5±1.4 kg/m²	3 conditions: - Control: rest period 60 min - Exercise free (F): exercise 60 min on cycle ergometer at 50%VO_{2peak} with free blood glucose decrease - Exercise maintained (M): exercise 60 min on cycle ergometer at 50%VO_{2peak} with blood glucose maintained above 4 mmol/L			- Correlations between SQ_F and reported EI in T2D (r=0.58, p≤0.01) **Other:** - SQ_{DTE} and SQ_H in control ≠ to F (p<0.05) - SQ_{DTE} and SQ_{PFC} in control ≠ to M (p<0.05)
Felix et al., 2013 [(32)]	n=10 (5 men,5 women) healthy adults Age range=27–55 yr BMI range= 20–25 kg/m²	Randomized cross-over study Protocol: Standardized BF, ad libitum lunch 8 BF preload conditions (7 cooked rice varieties with 50 g available carbohydrate): - Improved Malagkit Sungsong 2 - Sinandomeng (low amylose content) - NSIC Rc160 (low amylose	Before BF and every 15 min during the 1st hour and every 30 min during the 2nd hour after BF	SQ_H (mm/kJ) = (fasting rating - mean 120 min post-BF rating)/ energy content of BF*100	**Other:** - SQ_H was highest for the PSB Rc10 and lowest for the Improved Malagkit Sungsong 2, but the differences across rice types were not significant. - The short-term satiating capacity of rice was independent of its amylose content and glycemic index.

		content) - PSB Rc18 (intermediate amylose content), - IR64 (intermediate amylose content) and - - PSB Rc12 (intermediate amylose content) - PSB Rc10 (high amylose content) - 240-mL standard glucose drink (reference food)			
Harrington et al., 2013 [(43)]	n=82, Men: n=40 Age= 26.4±4.0 yr BMI= 23.5±2.5 kg/m² Women: n=42 Age= 26.9±4.7 yr BMI= 22.4±2.0 kg/m²	Observational study Protocol: Ad libitum lunch 3 groups (tertiles of activity-related energy expenditure; AREE): - Low AREE - Middle AREE - High AREE	Before and after ad libitum lunch	SQ_H, SQ_F, SQ_{DTE} and SQ_{PFC} (mm/kcal) = (rating pre-lunch - rating post-lunch)/ EI at lunch	**SQ, physical activity and energy expenditure:** Men: - EI middle AREE tertile < high tertile ($p=0.001$). - SQ_{DTE} high AREE < low and middle AREE ($p<0.05$). - SQ_H ($p<0.05$) and SQ_{PFC} ($p<0.001$) high AREE < middle AREE. - SQ_F high AREE > middle AERR ($p<0.05$).

McNeil et al., 2013 [(29)]	n= 75 overweight/ obese men Group 1 (Sleep duration) <u><7h/night</u>: n=34 Age= 41.6±6.6 yr BMI= 33.5±2.9 kg/m² <u>≥7h/night</u>: n=41 Age= 40.4±4.6 yr BMI= 33.8±3.0 kg/m² Group 2 (Sleep quality)	Observational study <u>Protocol</u>: Standardized BF (3066 kJ), ad libitum lunch, 3 groups: - Sleep duration - Sleep quality - Sleep timing	Before, immediately after, and every 10 min for 1h after the standardized BF	SQ_H, SQ_F, SQ_{DTE}, SQ_{PFC} (mm/kcal) = [fasting rating -60 min post-BF] /energy content of BF*100.	**<u>SQ and sleep quality and quantity</u>:** - No difference in SQ_H, SQ_F, SQ_{DTE}, SQ_{PFC} between groups. - Short-duration sleepers (<7h/night) SQ < sleepers with recommended sleep duration (≥7h/night) - Mean SQ sleep quality = mean SQ sleep timing.

PSQI score ≥5:
n=33
Age= 41.0±6.4 yr
BMI= 33.4±2.9 kg/m²

PSQI score <5:
n=42
Age= 40.9±5yr
BMI= 33.9±3.1 kg/m²

Group 3 (Sleep timing)

Midpoint of sleep > 02:30:
n=37
Age= 39.3±5.7 yr
BMI= 33.8±2.9 kg/m²

Midpoint of sleep ≤ 02:30:
n=38

	Age= 41.8±5.0 yr BMI= 33.8±3.2 kg/m²				
Schmidt et al,. 2014 [24]	n= 25 healthy males Age= 33±9 yr BMI= 29±3 kg/m²	Randomized, double-blinded, placebo-controlled, four-arm cross-over study Protocol: Standardized dinner day before, no BF, infusion, ad libitum lunch 4 infusions: - GLP-1 - PYY_{3-36} - GLP-1 + PYY_{3-36} - Placebo	5 min pre-infusion, and 25, 55, 85, 115 and 145 min after the beginning of the infusion) Ad libitum meal: 120 min after the beginning of the infusion	SQ_H, SQ_F, SQ_S, SQ_{PFC} (mm/mJ) = [rating pre-lunch - rating post-lunch]/EI at lunch Note: The authors define SQ as "Appetite Quotient"	**Other:** - SQ_{PFC} treatments < placebo ($p<0.05$) (↓ PFC) - SQ_S treatments < placebo ($p<0.01$) (↑Satiety)

Thomas et al,. 2014 [23]	**Men**: n=24 Placebo: n=8 Age=20.8 ±0.4 yr BMI=23.8±0.7 15 mg: n=8 Age=21.9±0.8 yr BMI=22.1±0.7 30 mg: n=8 Age=20.4±0.5 yr BMI=22.8±0.8 **Women**: n=23 Placebo: n=8 Age=22.4 ±1.0 yr BMI=21.5±0.7 15 mg: n=8 Age=20.4±0.5 yr BMI=22.0±0.8 30 mg: n=8 Age=19.9±0.7 yr BMI=22.4±0.9	Randomized, double-blind, placebo controlled study Protocol: Typical BF, test dose (2h before lunch), ad libitum lunch 3 test doses: - Placebo - 5-HT2C receptor agonist meta-chlorophenylpiperazine (mCPP) 15 mg - mCPP 30 mg	4h pre-lunch, 2h pre-lunch and every 30 minutes, during lunch, post-lunch, 1h post lunch.	SQ_H = ((quartile initial rating −quartile ending rating)/calories consumed at ad libitum lunch during quartile) Note: The authors define SQ as "Satiation Quotient"	**Other:** - Effect of quartile ($p<0.001$) and gender ($p<0.05$), a two-way interaction between gender and condition ($p<0.01$), and a three-way interaction between quartile, gender and condition ($p<0.05$). Men: - Effect of quartile ($p<0.01$) and condition ($p<0.05$). - SQ 30-mg mCPP < placebo ($p<0.05$) - ↑ SQ from quartile 2 to 3 ($p<0.05$). Women: - Effect of quartile ($p<0.01$), condition ($p<0.05$) and interaction between quartile and condition ($p<0.05$). Quartile 1: SQ 30-mg mCPP > placebo ($p<0.05$) Quartile 2: SQ 15-mg and 30-mg mCPP > placebo ($p<0.01$; $p<0.05$ respectively)

Bligh et al., 2015 [(21)]	n= 21 healthy males Paleolithic-type meal 1: n=17 Age= 27.9±13.2 yr BMI= 23.4±2.7 kg/m² Paleolithic-type meal 2: n=19 Age= 27.5±12.7 yr BMI= 23.4±2.6 kg/m² Refence meal: n=19 Age= 27.5±12.7 yr BMI= 23.4±2.6 kg/m²	Randomized cross-over study 3 standardized lunch conditions: - Paleolithic-type meal 1 (2326 kJ) (range ratios for protein; no cereals or dairy products) - Paleolithic-type meal 2 (1606 kJ) identical plant-based ingredients to PAL1, but normalized to the REF for fat, protein and energy in addition to available carbohydrates, by changing the fish, nut and strawberry content. - Reference meal (1602 kJ) macronutrient proportions, and contained protein, fruit and vegetables as well as cereals.	20 min before lunch, and 10, 25, 40, 55, 85, 115, 175 after the start of meal	SQ_{H}, SQ_{F}, SQ_{DTE} = NR	**SQ, energy intake and appetite control**: - SQ_{H}, SQ_{F}, SQ_{DTE} similarly increased in response to both Paleolithic meals.

Dalton et al., 2015 [14]	n = 30 women Age= 28.0±10.6 yr BMI= 23.1±2.9 kg/m²	Randomized cross-over study Protocol: Individualized and calibrated BF, ad libitum lunch, 4 BF conditions: - Calibrated to 20% resting metabolic rate (RMR) - Calibrated to 25% RMR - Calibrated to 30% RMR - Calibrated to 35% RMR	Before BF and 15,45,75 min post-BF	SQ_H (mm/kcal) = (rating before BF - mean of the 75 min post-BF ratings)/energy content of BF*100 The low satiety phenotypes were identified as those who had a low SQ at least 3 out of 4 conditions (n = 9) whereas the high satiety phenotypes were identified as those who had a high SQ at least 3 out of 4 conditions (n = 9).	**SQ, energy intake and appetite control:** - Average SQ across all RMR conditions was associated with RMR (r= -0.38, p<0.05), a greater implicit wanting fat bias (r= -0.49, p<0.01) and TFEQ disinhibition (r= -0.42, p<0.05). **→ Low SQ associated with a risk factors for overconsumption** **SQ and satiety phenotype:** - Low satiety phenotype had a lower average SQ across conditions compared to the high satiety phenotype (p<0.001).
Felix et al., 2016 [36]	n=12 healthy subjects (7 men, 5 women) Age range= 20-50 yr BMI range= 20-	Randomized, cross-over study Protocol: Standardized preload, ad libitum lunch 9 preload conditions: - Milled rice: IMS2 - Milled rice: NSIC Rc160	Before preload and every 15 min during the 1st hour and every 30 min during the 2nd	SQ_H, SQ_F, SQ_{DTE}, SQ_{PFC} (mm/kJ)= (fasting rating - mean 120 min post-preload rating)/ energy content of preload * 100	**Other:** SQ_H correlated with SQ_F (r= -0.72, p=0.05) SQ_{DTE} correlated with SQ_{PFC} (r= -0.72, p=0.05) Short term: - SQ glucose beverage < milled and brown

	25 kg/m²	- Milled rice: IR64 - Milled rice: PSB Rc10 - Brown rice: IMS2 - Brown rice: NSIC Rc160 - Brown rice: IR64 - Brown rice: PSB Rc10 - Reference food: 240mL standard glucose drink	hour after preload		rice (liquid foods elicit weaker satiety signals than solid foods). - Among milled samples, SQ_H was similar across rice varieties, confirming earlier results. - SQ_F, SQ_{DTE} and SQ_{PFC} comparable across rice types. The same trend was noted for brown rice. -SQ_H and post-meal cooked rice intake were independent of milled rice amylose content and glycemic index. <u>2h post-meal</u>: - The higher SQ for brown rice than milled rice was not translated into lower common cooked rice intake.
Hopkins et al., 2016 [(19)]	n=65 (26 men, 39 women) Age= 41.3±8.7 yr BMI= 30.90±3.8 kg/m²	Randomized cross-over study <u>Protocol</u>: Ad libitum BF, standardized lunch (800kcal), ad libitum dinner, ad libitum snack box 2 meal conditions: - HFLC day: high-fat/low-carbohydrate for all meals	Immediately before and after a meal, and at hourly intervals throughout the day (from 08:00 to 18:00).	SQ_H (mm/Kcal) = (rating pre-eating episode - rating post-eating episode)/intake of eating episode*100 SQ calculated for BF and lunch.	**<u>SQ, energy intake and appetite control</u>:** SQ LFHC > SQ HFLC after BF and lunch (p=0.006 and p=0.001, respectively).

		- LFHC day: low-fat/high-carbohydrate for all meals			
Salama et al., 2016 [11]	n=35 healthy adults Men: n=18 Age= 25.4±3.6yr BMI=23.6±2.1 kg/m² Women: n=13 Age= 22.6±3.3yr BMI=22.5±2.1 kg/m²	Randomized cross-over study Protocol: Standardized BF (men: 715 Kcal, women: 599Kcal) mental work/control, ad libitum buffet lunch, waist circumference, body composition 2 conditions (during 45 minutes): - Mental work (reading a text and writing a summary of 350 words) - Control (relaxed in a seated position)	Before BF, at the end of the two conditions, before and after the buffet, and every hour during the following 4 hours	SQ_H, SQ_F, SQ_{DTE}, SQ_{PFC} (mm/kcal) = (Post-meal rating (T0)- Pre-meal rating (T-15)) / energy content of the meal *100. SQ calculated at BF and lunch	**SQ and anthropometrics variables**: - A high waist circumference was correlated with lower SQ_F after mental work (r = 0.43, p<0.05). Positive relationship between % fat mass and : - SQ_F after mental work (r=0.45, p<0.05) and rest (r=0.55, p<0.01). - SQ_{PFC} after mental work (r=0.71, p<0.001) and rest (r=0.44, p<0.05). - SQ_{DTE} after mental work (r=0.46, p<0.01) and rest (r=0.46, p<0.05). - SQ_H after rest (r=0.44, p<0.05).
Beaulieu et al., 2017 [25]	n=39 non-obese adults High levels of physical activity: n=20 (10 men,	Randomized cross-over study Protocol: Individualized BF (ad libitum on first test day standardized to quantities consumed on second test day),	Pre and post-BF, 60, 120, 180 min post-BF, pre and post-lunch	SQ_H (mm/kcal) = (rating before lunch - rating after lunch)/EI at lunch*100	**SQ, energy intake and appetite control**: - SQ at lunch: effect of condition (p<0.001), SQ HCHO > SQ HFAT.

	10 women), Age= 29.9±9.6 yr BMI= 22.6±1.9 kg/m² Low levels of physical activity: n=19 (8 men, 11 women), Age= 30.4±9.3 yr BMI=23.1±2.7 kg/m²	ad libitum lunch 2 lunch conditions - HFAT: high-fat ad libitum lunch - HCHO: high-carbohydrate ad libitum lunch			
Defries et al., 2017 [22] **Seed study**	n=38 (10 men, 28 women) Age = 37.7 yr (range 20-67) BMI= 24.8 kg/m² (range 18.7-30.4)	Single-site, randomized, controlled, cross-over study Protocol: Typical BF (replicated on subsequent test days), standardized snack food, ad libitum lunch, food diary remainder of day 2 snack conditions (140 kcal): - Roasted buckwheat groats	At 30-min intervals up to 180 min after the first bite of the snack.	SQ_H (mm/kcal)= (rating before snack – rating after snack)/ energy content of the snack	**SQ, energy intake and appetite control:** - Effect of time for SQ buckwheat groats ($p < 0.0001$).

		- Corn nuts (reference food)			
Defries et al., 2017 [22] **Pita study**	n=38 (11 men, 27 women) Age= 33.5 yr (range 20-67) BMI= 24.4 kg/m² (range 18.7-30.4)	Single-site, randomized, controlled, cross-over study <u>Protocol</u>: individualized BF, standardized snack food, ad libitum lunch, food diary remainder of day 2 snack conditions (~135 kcal): - Gluten-free pita bread made from buckwheat and pinto bean flour - Gluten-free rice bread (reference food)	At 30-min intervals up to 180 min after the first bite of the snack.	SQ_H (mm/kcal)= (rating before snack – rating after snack)/ energy content of the snack	**<u>SQ, energy intake and appetite control</u>:** - Effect of time (p<0.0001) and snack (p=0.0002) for the SQ buckwheat pita (SQ buckwheat pita > SQ rice bread).
Gonzalez et al., 2017 [33]	<u>Experiment 1</u>: n=10 non-obese men, Age= 22±1 yr BMI= 24.8±1.6 kg/m² <u>Experiment 2</u>:	Randomized, double blind, cross-over study (data from 2 experiments pooled for analyses) <u>Protocol</u>: Liquid meal Experiment 1: 2 liquid meal conditions (repeated twice) - Low energy: 579 kJ	Within 5 min before liquid meal, and every 15 min over 60 min post-meal	Composite SQ (µm/kJ)= (baseline appetite - postprandial appetite AUC)/energy content of meal Composite SQ	**<u>SQ, energy intake and appetite control</u>:** The reproducibility of the SQ is better in response to the ingestion of meals of higher energy content compared to lower energy meals.

	n=10 non-obese men, Age=21±4 yr BMI=24.2±2.3 kg/m²	- Moderate energy: 1776 kJ Experiment 2: 2 liquid meal conditions (repeated twice) - Low energy: 828 kJ - High energy: 4188 kJ		calculated with (hunger, (100-fullness), satisfaction and PFC)/4.	
McNeil et al., 2017 [31]	n = 18 (12 men, 6 women) Age=23±4 yr BMI=22.7±2.7 kg/m²	Randomized cross-over study <u>Protocol</u>: Individualized BF (ad libitum on preliminary session and standardized to quantities consumed on subsequent sessions), ad libitum lunch 3 conditions: - Control (habitual bed- and wake-time) - 50% sleep restriction with an usual bedtime and advanced wake-time - 50% sleep restriction with a delayed bedtime and habitual wake-time	Before BF and 0, 30, 60, 90, 120, 150, 180 min post-BF.	SQ_H, SQ_F, SQ_{DTE}, SQ_{PFC} (mm/kcal) = [fasting rating - mean post-meal rating] /energy content of BF *100.	**<u>SQ and sleep quality and quantity</u>:** - No difference in SQ between sessions. - No correlations between changes in sleep stage durations with mean SQ between sessions.

Polugrudov et al., 2017 [(20)]	n=66 Social JetLag (SJL) ≤1h: n=17 (3 men, 14 women), Age=23.7±2.9 yr BMI=21.2±2.5 kg/m² SJL 1h to ≤2h: n=28 (10 men, 18 women) Age=22.8±3.2 yrs BMI= 22.2±3.2 kg/m² SJL>2h: n=21 (6 men, 15 women) Age= 23.2±4.1 yr BMI= 23.4±4.6 kg/m²	Randomized Trial Protocol: Ad libitum BF 3 groups: - SJL ≤1 h - SJL 1h to ≤ 2 h - SJL> 2 h	Before BF and at 30, 60, 90, and 120 min after	SQ_H, SQ_F, SQ_S, SQ_{PFC} (mm/kcal)= [fasting rating - mean post-meal rating]/EI at BF*100.	**Other:** - Mean SQ (mean value of SQ_H, SQ_F, SQ_S, SQ_{PFC}) in SJL 1-2h and SJL >2h groups lower than SJL ≤ 1h group ($p<0.01$).

Au-Yeung et al., 2018 [30]	n= 16 (4 men, 12 women) Age=26±19 yr (range 18–62), BMI=23.1 ±3.2 kg/m²	Randomized, single-blind, controlled, dose-response cross-over study <u>Protocol</u>: Standardized preload, ad libitum dessert 3 preload conditions: - Control: all pasta with no Konjac Glucomannan (KGM)-gel (1849 kJ) - 50-KGM: half pasta and half KGM-gel (1084 kJ) - 100-KGM: no pasta and all KGM-gel (322 kJ)	Baseline (before preload), 15, 30, 45, 60, 75 and 90 min after the first bite of the preload.	SQ_H, SQ_{DTE}, SQ_{PFC} (mm/kJ)= (baseline rating - postprandial rating)/ energy content of preload SQ_F (mm/kJ)= (postprandial rating – baseline rating)/ energy content of preload Composite SQ calculated with (hunger, (100-fullness), DTE and PFC)/4.	**<u>SQ, energy intake and appetite control</u>:** SQ_H, SQ_F, SQ_{DTE}, SQ_{PFC} and composite SQ were significantly increased in response to 100-KGM ingestion compared with 50-KGM and control with no difference between 50-KGM and control.
Hansen et al., 2018 [18]	n=39 (11 men, 28 women) Age=26.3 ± 10.9 yr BMI= 24.4 ± 3.1 kg/m²	Double-blind randomized cross-over study <u>Protocol</u>: Standardized BF, ad libitum meal 3 BF conditions (including 80 g cheese): - HP/LF: high-protein/low-fat hard cheese (1721 kJ)	Before and 15 min after the BF and at 30-min intervals after BF during 180 min and before and after ad libitum test	Composite SQ (mm/kJ) = (pre-meal rating−post-meal rating)×100/ EI of the food consumed Composite SQ calculated with (satiety	**<u>SQ, energy intake and appetite control</u>:** - ↑ feeling of satiety from the HP/LF cheese tended to lower EI compared with the LP/HF cheese - HP cheese content ↑ satiety and ↓ EI when included as part of a diet.

		- HP/HF: high-protein/high-fat hard cheese (2000 kJ) - LP/HF: low-protein/high-fat cream cheese (1796 kJ)	meal	+ fullness + (100-hunger) + (100-DTE) + (100-PFC)/5 SQ calculated at BF and lunch Note: The authors define SQ as "Appetite Quotient"	
Hollingworth et al., 2018 **(15)**	n= 42 females Age=26.0 ±7.9 yr BMI=22.0 ±2.0 kg/m²	Randomized cross-over study Protocol: mid-morning snack, ad libitum EI 3 snack conditions: - Raw almonds - Savory crackers - Water	NR	SQ = NR	**SQ, energy intake and appetite control**: - Consumed energy, reported craving for sweet foods: low SQ > high SQ - Levels of hunger, desire to eat and prospective consumption: low SQ > high SQ - Satiating efficiency in low SQ: almonds > snack (crackers) - Low SQ = behavioral and psychological characteristics associated with risk for overconsumption (but substitution of certain snack foods may improve the satiety responsiveness of these individuals)

Martini et al., 2018 [27]	n= 20 females Age= NR BMI= <25 kg/m²	Randomized cross-over study <u>Protocol</u>: Own low-fiber BF, standardized lunch, ad libitum snack 5 pasta lunch conditions: - High fiber - High fiber + high protein - High protein (soy protein) - High protein (egg white) - Control (standard commercial pasta)	Before and after lunch, every 30 min for 2 h until snack, before and after snack	SQ_F, SQ_{DTE}, SQ_S SQ 1 (cm/kcal)=(rating before lunch-rating after lunch)/ Energy content of lunch*100 SQ 2 (cm/kcal)=(rating before lunch-rating before snack)/ Energy content of lunch*100 SQ 3 (cm/kcal)=(rating before lunch-rating after snack)/ (Energy content of lunch + snack)*100	**<u>SQ, energy intake and appetite control</u>:** - SQ_F for all formulations > SQ_F control pasta immediately after lunch and over the subsequent 2 h. - SQ_{DTE} for High fiber + high protein pasta < SQ_{DTE} for control pasta after lunch and after snack consumption - Only high fiber pasta showed a higher SQ_S compared to control.
Thivel et al., 2019 [37]	n=19 normal weight (10 men, 9 women) Age= 21 ± 1 yr BMI= 22.3±2.9 kg/m²	Randomized controlled cross-over study <u>Protocol</u>: Standardized BF (500 kcal), exercise/control, standardized lunch (women: 750 kcal, men: 900 kcal) 3 conditions:	Before and after BF, before and after exercise/rest, before and after lunch, and 30 min and	SQ_H, SQ_F, SQ_{DTE}, SQ_{PFC} (mm/kcal) = (pre meal rating – mean 60 min post-meal rating) / energy content of lunch*100.	**<u>SQ, physical activity and energy expenditure</u>:** - No difference in SQ_F across conditions. - SQ_H CON > LIE and HIE ($p \leq 0.05$) (no difference between LIE and HIE) - SQ_{DTE} CON > HIE ($p \leq 0.01$) (no difference between CON and LIE, and between LIE

	- CON: rest during 45 min - Low intensity exercise (LIE): 45 min cycling at 50%VO_{2max} - High intensity exercise (HIE): 30 min cycling at 75%VO_{2max}	60 min after the test meal		and HIE) - SQ_{PFC} HIE < CON (p=0.02) (no difference between CON and LIE, and LIE and HIE)

Protocol are detailed only the relevant of SQ; values are presented as means ± SD (standard deviation); AS: appetite sensation; EI: energy intake; BF: Breakfast; BW: Body Weight, NR: Not Reported. DTE: Desire To Eat; F: Fullness; H: Hunger, PFC: Prospective Food Consumption; S: Satiety; SQ: Satiety Quotient.

Table 4: Data detailed for children and adolescents acute studies

Study	Population characteristics	Design	VAS timing	SQ equation	Main results
Albert et al., 2015 [38]	n = 12 boys Age= 17±1,6 yr BMI= 23.1±3.1 kg/m²	Randomized cross-over study <u>Protocol</u>: Standardized BF, exercise (70%VO_{2max}), ad libitum lunch (12:00 pm), ad libitum dinner (5:00am) 2 conditions: -ExMeal: Exercise at 11:15am meal 12:00pm -Ex_{delay}Meal: Exercise 09:00am meal 12:00pm	Before and after lunch and dinner	SQ_H (mm/kJ) = (pre-lunch rating−post-lunch rating) /EI at lunch*100	**<u>SQ, physical activity and energy expenditure</u>:** - No difference SQ between conditions at lunch and dinner.
Fillon et al., 2020 [39]	n=15 (6 boys and 9 girls) Age=13.1±1.4 yr BMI= 34.7±6.0 kg/m² (z-BMI 2.3±0.3)	Randomized controlled study <u>Protocol</u>: Standardized BF, exercise/rest condition, ad libitum lunch (12:00), ad libitum dinner (18:00) 3 conditions: - rest condition (CON) - 30-min exercise (65%VO_{2max}) 180 min before lunch (EX-180) - 30-min exercise (65%VO_{2max})	Before meal, post-meal, 30 and 60 min after meal for ad libitum lunch and dinner	SQ_H, SQ_S, SQ_{DTE} and SQ_{PFC} (mm/kcal) = (pre-lunch rating – mean post-lunch and 60 min post-lunch rating) / EI at lunch*100	**<u>SQ, physical activity and energy expenditure</u>:** - SQ_H CON < SQ_H EX180 and EX30 - SQ_{PFC} CON < SQ_{PFC} EX180 and EX30 - SQ_{DTE} CON < SQ_{DTE} EX180 and EX30

		30 min before lunch (EX-30)			
Kral et al., 2020 **[41]**	n=212 LR-NW: n=60 (28 boys and 32 girls) Age=8.3±0.7 yr z-BMI= -0.2±0.7) HR-NW: n=77 (29 boys and 48 girls) Age=8.3±0.8 yr z-BMI=0.2±0.6) HR-OB: n=75 (29 boys and 46 girls)	Randomized cross-over study Protocol: Standardized preload, ad libitum BF (9:00am), ad libitum lunch (12:00pm), ad libitum dinner (4:30pm), snack. 2 conditions: -LED: Low Energy Density preload (100g, 100kcal) -HED: High Energy Density preload (100g, 160kcal) 3 groups: LR-NW: Normal Weight children with Low Risk for obesity HR-NW: Normal Weight children with High Risk for obesity HR-OB: Overweight / Obese	Before and after preload and BF, 60, 120, 180 minutes after BF.	SQ_H, SQ_S, SQ_{DTE} and SQ_{PFC} (mm/kcal) = (pre-preload rating – mean post-preload and 15 min post-preload rating) / EI at preload *100	**SQ, energy intake and appetite control:** LED SQ_H and SQ_{PFC} > HED SQ_H and SQ_{PFC} LED SQ_F < HED SQ_F SQ_H (p=0.005), SQ_{DTE} (p=0.01), SQ_{PFC} (p=0.02) predict BF EI. SQ_{DTE} predict daily EI (p=0.001) **SQ and anthropometrics variables**: No ≠ between groups for all SQ (p>0.10)

	Age=8.5±0.8 yr z-BMI=1.7±0.5)	children with High Risk for obesity			
Thivel et al., 2020 [42]	n= 14 (6 boys, 8 girls) Age= 12.8±0.9 yr BMI=34.8±5.7 kg/m² (z-BMI 2.3±0.4)	Randomized controlled study Protocol: Standardized BF, exercise/rest condition, ad libitum lunch (12:00), ad libitum dinner (18:00) 3 conditions: - rest condition (CON) - 30-min exercise (65%VO_{2max}; EX) - 30-min exercise (65%VO_{2max}) + energy replacement (ER+R).	Before meal, post-meal, 30 and 60 min after meal for ad libitum lunch and dinner	SQ_H, SQ_S, SQ_{DTE} and SQ_{PFC} (mm/kcal) = (pre-lunch rating – mean post-lunch and 60 min post-lunch rating) / EI at lunch*100	**SQ, physical activity and energy expenditure:** - No difference between conditions for SQ_H, SQ_S, SQ_{DTE} and SQ_{PFC}

Values are means ± SD; EI: energy intake; VAS: Visual Analogue Scale; DTE: Desire To Eat; F: Fullness; H: Hunger, PFC: Prospective Food Consumption; S: Satiety; BF: Breakfast. SQ: Satiety Quotient.

Table 5: Population, design, methods and main results of adult chronic studies

Study	Population characteristics at baseline	Design	VAS Timing	SQ Equation	Main Results
Chaput et al., 2007 [47]	n= 11 men, Age= 38±16.6 yr BMI= 33.4±3 kg/m²	Interventional study <u>Duration</u>: after a 10±1 kg BW loss was achieved <u>Intervention</u>: Diet and exercise <u>Assessment frequency</u>: baseline, after 5±1 kg BW loss (Phase 1) and after 10±1 kg BW loss (Phase 2). <u>Assessments protocol</u>: Anthropometric measurements, standardized BF (kcal), ad libitum lunch	Before and after lunch	SQ_H, SQ_F, SQ_{DTE} and SQ_{PFC} = (rating pre-lunch - rating post-lunch)/EI at lunch	**<u>SQ and anthropometrics variables</u>**: - No difference in SQ between phases
Drapeau et al., 2007 [10]	n=253 <u>Men</u>: n= 142 Age= 42.7±7.15 yr BMI= 32.5±3.6 kg/m²	Observational study Subjects were selected from different weight loss studies (data pooled for analyses) **Study 1:** <u>Duration</u>: 1 year,	Before, immediately after, and every 10 min for 1-h after BF	SQ_H, SQ_F, SQ_{DTE} and SQ_{PFC} (mm/kcal) = (fasting rating - mean 60 min post-meal rating)/energy content	<u>Baseline data</u>: **<u>SQ, energy intake and appetite control</u>:** - SQ_F was correlated⁻ with ad libitum EI (r= -0.14, p<0.05) (just in women

	Women: n = 111 Age= 41.3±7.4 yr BMI= 33.7±3.2 kg/m²	Intervention: Topiramate **Study 2**: Duration: 4 weeks, Intervention: Rimonabant **Study 3**: Duration: 15 weeks, Intervention: Diet + Fenfluramine/placebo **Study 4**: Duration: 30 weeks, Intervention: Diet + Physical activity **Study 5**: Duration: 15 weeks, Intervention: Diet + calcium and vit. D/placebo **Study 6**: Duration: 15 weeks, Intervention: Diet + micronutrient supplementation/placebo Assessment frequency: Baseline and post-intervention Assessment protocol: Anthropometrics, standardized BF (men 733 kcal, women 599 kcal), ad	of BF*100	(r= -0.22, p<0.01)). **Other**: - Men SQ was lower compared with women (p<0.0001). Longitudinal data: **SQ and anthropometrics variables**: - ↑ SQ_{DTE} (p<0.0001), SQ_{H} (p<0.001), SQ_{PFC} (p<0.0001) in men after weight loss, but not in women. - Changes in SQ_{DTE} were related with changes in BW (r= -0.14, p<0.01).

		libitum lunch, self-reported energy intake			
Rodriguez-Rodriguez et al., 2008 [45]	n=57 women, Age=27.8±4.7 yr Diet V: n=28 BMI=27.6±2.5 kg/m² Diet C: n=29 BMI=28.3±3.4 kg/m²	Randomized study Duration: 6 weeks Intervention: 2 hypoenergetic diet groups - Diet V: Consumption of vegetables increased - Diet C: Consumption of cereals (especially BF cereals) increased Assessment frequency: Baseline and post-intervention Assessment protocol: Anthropometrics, standardized BF, lunch, dinner, snack, self-reported of food intake	Before and after meals	SQ_H (cm/kcal) = (fasting rating post-meal rating)/energy consumed at a meal*100	**SQ, energy intake and appetite control:** - At baseline, lunch SQ diet C < diet V, but not post-intervention because SQ diet C ↑. Post-intervention, SQ ↑ with lunch and dinner, as did the mean SQ (for all meals taken as a whole). - Post-intervention: mean SQ diet C > diet V

Gilbert et al., 2009 [48]	n=54 women Age= 39.9±7.5 yr BMI= 32.9±3.5 kg/m²	Interventional study Duration: 4 or 6 months Intervention: energy restriction program (2900 kJ/day) Assessment frequency: baseline and post-intervention Assessments protocol: Anthropometrics, standardized BF (2504 kJ)	Before and after BF, 1h after BF	SQ_H, SQ_F, SQ_{DTE} and SQ_{PFC} (mm/kJ) = (fasting rating -60 min post-meal rating)/energy content of BF*100	**Other:** - SQ_{DTE} (p=0,03) was the only significant change among the SQ and AUC values.
King et al., 2009 [50]	n= 58 (19 men, 39 women) Age=39.6±9.8 yr BMI= 31.8±4.5 kg/m²	Interventional Study Duration: 12 weeks Intervention: Exercise program (500 kcal per session, 70% of individual's maximum heart rate 5 days/week) Assessment frequency: baseline and post-intervention Assessments protocol: Anthropometrics, individualized BF (ad libitum at baseline and quantities	Immediately before, after, and periodically in between meals	SQ_H (mm/kcal) = (rating before the eating episode -rating after the eating episode)/energy content of BF *100	**SQ, physical activity and energy expenditure:** SQ of the standardized BF ↑ over the 12-week period of exercise. This effect was maintained for 4 h after the meal.

		replicated post-intervention; 406±5 kcal), ad libitum lunch and dinner, evening snack box			
Halford et al., 2010 [56]	n= 30 women Age=46.0±12.9 yr BMI= 34.6±3.3 kg/m²	Double blind, placebo controlled crossover study Duration: 7 days Intervention: 3 conditions: - Sibutramine 10 mg a day - Sibutramine 15 mg a day - Placebo Assessment frequency: before and after drug administration (7 days) Assessment protocol: standardized BF (2173 kJ), ad libitum lunch	Before and after BF, 10:00, 11:00, 12:00, before and after lunch at 13:00, 15:00, 16:00, 17:00	SQ_H (mm/kJ) = (pre-lunch rating - post-lunch rating) /EI at lunch	**Other:** - SQ in the 10 mg group > placebo (p=0.03). - SQ in 15 mg = SQ to placebo (smaller change in hunger rating pre- to post-test meal because of a proportionally greater reduction in food intake in this condition).

Jönsson et al., 2010 [44]	n=29 men ischemic heart disease patients with impaired glucose tolerance or T2D, and waist circumference >94 cm Age= NR BMI= NR	Interventional randomized study Duration: 12 weeks Intervention: 2 diet groups - Paleolithic diet (n=14): based on lean meat, fish, fruit, vegetables, root vegetables, eggs, and nuts - Mediterranean diet (n=15): whole-grain cereals, low-fat dairy products, potatoes, legumes, vegetables, fruit, fatty fish, refined fats rich in monounsaturated fatty acids and alpha-linolenic acid. Assessment frequency: measured once at 15 ± 5 days Assessment protocol: 4-day food record, appetite sensation, anthropometrics, BW	At meal initiation and 30 min after meal initiation (free-living measurements)	SQ_S for energy (rating/MJ) and weight (rating/kg) = (rating pre-eating episode - rating post-eating episode)/food intake of eating episode Satiety measured with 7-point scale anchored at -3 (very hungry) to +3 (very full)	**SQ, energy intake and appetite control:** - SQ for energy Paleolithic group > Mediterranean group (p=0.057) and without the outlier becomes significant (p=0.02). - Correlation between SQ for energy and EI (r= 0.54, p=0.004), absolute intake of CHO (r=0.50, p=0.007), glycemic load (r=0.50, p=0.007), saturated fatty acids (r=0.41, p =0.03) and sodium (r=0.51, p =0.007).

Caudwell et al., 2013 [57]	n=107 adults with overweight/obesity Men: n=35 Age=41.3±8.6 yr BMI= 30.5±8.6 kg/m² Premenopausal women: n=72 Age= 40.6±9.5 yr BMI= 31.8±4.3 kg/m²	Interventional study Duration: 12 weeks Intervention: Aerobic exercise (500 kcal per session, 70% of individual's maximum heart rate 5 days/week) Assessment frequency: Baseline and post-intervention Assessment protocol: Anthropometric measurements, individualized standardized-energy BF, standardized lunch and ad libitum dinner, evening snack box	Immediately before and after each meal, and at hourly intervals between	SQ_H (mm/kcal) = (rating before BF-rating after BF)/EI of the BF *100	**SQ, physical activity and energy expenditure:** - Exercise program ↑ SQ in males and females (p<0.0001). - There was a difference in sex (p=0.014); SQ females > SQ males at baseline and post-intervention.
Jönsson et al., 2013 [55]	n= 13 (10 men, 3 women) T2D Age= NR BMI= NR	Randomized cross-over study Duration: 3 months Intervention: 2 conditions: - Diabetes diet (current guidelines) - Paleolithic diet	At meal initiation and 30 min after meal initiation (free-living measurements)	SQ_S for energy (rating/MJ), weight (rating/kg), energy density (rating*g/kJ), glycemic load (rating/kg) and	**SQ, energy intake and appetite control:** - SQ for energy Paleolithic diet > diabetes diet (p=0.004). - No differences between the diets in SQ for weight per meal and GI per

		Assessment frequency: baseline and after 3 (in-between crossover) and 6 months Assessments protocol: 4-day weighed food record at 6 weeks		glycemic index (RS) = (rating pre-eating episode - rating post-eating episode)/food intake of eating episode Satiety measured with 7-point scale anchored at -3 (very hungry) to +3 (very full)	meal. - SQ for energy per meal correlated with triglyceride levels and vitamin B6 intake (r=0.60 and 0.64, p=0.03 and 0.02, respectively). - SQ for energy density correlated with water from food (r=0.71, p =0.01), and SQ for glycemic load correlated with BMI and spirits (r= −0.84 and 0.59, p=0.0003 and 0.03, respectively).
McNeil et al., 2014 [9]	n=102 premenopausal women, Age= 49.9±1.9 yr BMI= 23.3±2.2 kg/m²	Observational study Duration: 5 years Assessment frequency: baseline and every 1 year Assessment protocol: Anthropometric measurements, standardized BF (575 kcal), ad libitum lunch, 7-day food diary	VAS: Before, immediately after and every 30 min for 3h post-BF consumption. SQ: 60 and 180 min post-BF consumption.	SQ_H, SQ_F, SQ_{DTE} and SQ_{PFC} (mm/kcal) = [fasting rating - mean post-meal rating]/energy content of the test meal *100	**SQ, energy intake and appetite control**: SQ_F, SQ_{PFC}, mean SQ explained 5 to 14% of the variance in ad libitum energy and macronutrient intake at lunch at 1, 3-5 years. - SQ_F, SQ_{PFC} explained 8 and 14% of the variance in daily (7-day food diary) energy and carbohydrate intakes at year 4. **SQ and anthropometrics variables**:

- year 1: BW women with a lower mean SQ < higher mean SQ (p=0.02).
- Changes in BW correlated with delta SQ_F at 60(r=0.34; p=0.004) and 180 (r=0.30; p=0.01) min between years 1 and 5.
- Changes in FM correlated with delta SQ_F at 60 min between years 1 and 5 (r=0.24; p=0.04).
- Delta FM correlated^{-} with i) delta SQ_H at 60 (r= -0.34; p=0.02) and 180 min (r= -0.34; p=0.02), ii) delta SQ_{PFC} at 60 (r= -0.33; p=0.02) and 180 (r= -0.32; p =0.02) min, between years 4 and 5.
- Changes in waist circumference associated with delta SQ_{DTE} at 60 min (r= -0.31; p=0.02), delta SQ_H at 60 min (r= -0.32; p=0.02), delta SQ_F at 60 (r= -0.31; p=0.02) and 180 min (r= -0.29; p=0.03), and delta mean SQ at 60 min (r= -0.32; p=0.02) between years 3 and 4.

Other:

					- No difference in SQ between menopausal status groups (premenopausal, menopausal transition and postmenopausal) at years 2 – 5.
Bédard et al., 2015 [49]	n=70 Men: n=38 Age=42.6±7.4 yr BMI= 29.0±3.1 kg/m² Premenopausal women: n=32 Age=41.2±7.4 yr BMI= 29.6±5.6 kg/m²	Interventional study Duration: 16 weeks Intervention: isoenergetic MedDiet standardized and personalized menu (Assessment frequency: Every wednesday from week 1 to 4. Assessments protocol: Individualized BF, lunch and dinner (2500 kcal/d)	Before and immediately after each meal	SQ_F (mm/kcal) = (post-meal rating – pre-meal rating)/energy content of the test meal*100	**SQ, energy intake and appetite control:** Mean SQ_F (BF, lunch and dinner) correlated with EI in men (r= -0.48, p=0.003) **Other:** - No change in SQ from first to fourth week for both men and women.

Carbonneau et al., 2015 **(52)**	n=141 Low-fat label normal weight: n=23 Age=43.5±10.8 yr BMI=22.4±1.6 kg/m² Low-fat label obese: n=23 Age=52.3±11.5 yrs BMI= 34.7±3.9 kg/m² Energy label normal weight: n=25 Age= 37.7±12.6 yr BMI= 21.8±1.9 kg/m² Energy label obese: n=23 Age= 46.0±14.3 yr	Randomized, controlled trial Duration: 10 days Intervention: 3 meals per day under ad libitum conditions 3 groups: - Low-fat label posted on lunch meal main course - Energy label (energy content of main course and average daily needs) - No label (control) Assessment frequency: Daily Assessments protocol: BF, lunch and dinner ad libitum	Before and immediately after meal	SQ_H and SQ_F (mm/kcal) = (fasting rating - post-meal rating)/energy content of the meal*100	**Other:** - No difference between groups on 10-d mean for SQ_H and SQ_F. - Significant labelling group by time interaction was observed for the 3-d mean SQ_H (p= 0.046). SQ_H in the energy label group at days 8 − 10 < days 1 − 3 (no difference between low-fat and no-label groups).

	BMI= 34.5±4.9 kg/m² No label normal weight: n=22 Age= 42.6±12.4 yr BMI= 22.8±1.5 kg/m² No label obese: n=25 Age= 53.0±11.0 yr BMI= 32.6±2.3 kg/m²				
Golloso-Gubat et al., 2016 [46]	n=34 healthy male adults Age=27.7±6.2 yr BMI= 22.1±1.9 kg/m²	Randomized crossover study Duration: 6 weeks Intervention: 3 conditions: - BF with brown rice - BF with white rice - Control Assessment frequency: Before and after each condition Assessment protocol: Standardized BF (500 Kcal	Before, and 15, 30, 45, 60, 90, 120, 150, 180, 240 min after meals	SQ_H (mm/kcal) = (mean fasting ratings - mean 240 min post-prandial ratings)/energy content of BF*100.	**SQ, energy intake and appetite control:** - Mean SQ of brown rice > white rice (p=0.045).

		kcal; including 160 g cooked rice)			
Arguin et al., 2017 [12]	n=69 men Control Diet Low Satiety Phenotype (LSP): n=15 Age= 41.0±6.3 yr BMI= 34.1±3.5 kg/m² Control Diet High Satiety Phenotype (HSP): n=19 Age= 41.9±5.5 yr BMI= 33.9±2.8 kg/m² Satiating Diet LSP: n=17 Age= 40.4±6.2 yr BMI= 33.6±3.0 kg/m²	Randomized controlled trial Duration: 16 weeks Intervention: Diet intervention 2 groups: - Control: 10–15% protein, 55–60% carbohydrate and 30% fat - Satiating: 20–25% protein, 45–50% carbohydrate and 30–35% fat Assessment frequency: Baseline and post-intervention Assessments protocol: Anthropometrics, standardized BF (733 kcal), TFEQ	Before, immediately after and at 10 min intervals until 1h then 90 and 120 min after BF.	SQ_H, SQ_F, SQ_{DTE} and SQ_{PFC} (mm/kcal) = (fasting rating - mean of the 60-min post-meal rating/ energy content of BF) *100 Low satiety phenotype: mean SQ<8mm/100 kcal High satiety phenotype: mean SQ≥8mm/100 kcal	**SQ and satiety phenotype:** - ↑ all SQ for LSP in the satiating diet (all $p<0.01$). - SQ_H ↑ for HSP in the satiating diet ($p<0.05$). - SQ_{PFC} tended to ↓ in the HSP-control subgroup ($p=0.05$). - After adjustment for baseline variables: significant effect of diet for the changes in SQ_H, SQ_F, SQ_{PFC} and mean SQ (all $p<0.05$), with greater increases in SQ for the satiating diet.

	<u>Satiating Diet</u> <u>HSP</u>: n=18 Age= 42.55±5.0 yr BMI= 32.9±2.9 kg/m²				
Sanchez et al., 2017 [51]	n=125 <u>Probiotic group</u>: n=62 Age=35.0±10.0 yr BMI= 33.8±3.3 kg/m² <u>Placebo</u>: n=63 Age= 37.0±10.0 yr BMI= 33.3±3.2 kg/m²	Double-blind, randomized, placebo controlled study <u>Duration</u>: 24 weeks <u>Intervention</u>: 12-week moderate energy restriction including 2 daily capsules of probiotic/placebo (Phase 1), followed by 12 weeks of weight maintenance (Phase 2) <u>Assessment frequency</u>: baseline, week 12, week 24 <u>Assessments protocol</u>: Anthropometrics, standardized BF (men 733 kcal, women 599 kcal), ad libitum lunch, TFEQ	Before, immediately after, and every 10 min for 1 h after the standardized BF	SQ_H, SQ_F, SQ_{DTE} and SQ_{PFC} (mm/kcal) = (fasting rating - mean of the 60-min post-meal ratings) /energy content of test meal) *100	**<u>Other</u>:** - Final sample: n=93, Probiotic: n=45, Placebo: n=48 - For women and men, the SQ_{DTE} probiotic group at lunch > placebo group after Phase 1 (men p = 0.03; women p = 0.02). The same trend was observed for the changes in SQ_{DTE} at BF but not significantly.

Buckland et al., 2019 [58]	n=52 women Age= 41.2±12.5 yr BMI= 34.0±3.6 kg/m²	Randomized controlled trial Duration: 14 weeks Intervention: Weight loss program with low energy density meal and high energy density meal at week 3 and 12. Assessment frequency: week 3 and 12. Assessments protocol: Anthropometric measurements, TFEQ, craving control, food reward, low energy density (LED) and high energy density (HED) test days: individualized BF and lunch, ad libitum dinner and evening snack box	Before and after each meal and at hourly intervals	SQ_F (mm/kcal) = (mean of the 180-min post-meal rating - fasting rating/energy content of BF)*100 Low satiety phenotype: SQ<4.5mm/100 kcal High satiety phenotype: SQ≥8.5mm/100 kcal	**SQ, energy intake and appetite control:** - Preference (explicit liking and implicit wanting) for and consumption of HED food: LSP > HSP **SQ and anthropometrics variables**: - ↓ BW and ↓ waist circumference: LSP < HSP **Other:** - Control over eating and weight loss program adherence: LSP < HSP

Drapeau et al., 2019 [53]	n=100 Low Satiety Responsiveness (LSR): n=50 (23 men, 27 women) Age=37.8±9.5 yr BMI= 33.7±3.9 kg/m² High Satiety Responsiveness (HSR): n=50 (6 men, 44 women) Age= 39.6±7.8 yr BMI= 32.6±3.3 kg/m²	Observational study Subjects were selected from different weight loss studies Study 1 & 2: Duration: 15 weeks, Intervention: caloric restriction (-700 kcal/day) Study 3: Duration: 12 weeks, Intervention: caloric restriction (-500 kcal/day) Assessment frequency: Baseline and post-intervention Assessment protocol: Anthropometrics, standardized BF (men 733 kcal, women 599 kcal), ad libitum lunch, TFEQ, State-Trait Anxiety Inventory	Before, immediately after, and 10, 20, 30, 40, 50, and 60 min after BF	SQ_H, SQ_F, SQ_{DTE} and SQ_{PFC} (mm/kcal)= (fasting rating - mean of the 60-min post-meal rating) /energy content of BF*100 Low satiety phenotype: mean SQ<8mm/100 kcal High satiety phenotype: mean SQ≥8mm/100 kcal	Baseline: **SQ, energy intake and appetite control:** - Level of external locus for hunger: LSP > HSP **SQ and satiety phenotype:** - Mean SQ and for each rating: LSP < HSP. **SQ and sleep quality and quantity:** - Level of PSQI total score: LSP > HSP(indicating lower sleep quality compared to the HSP group) **Other:** - Present-state anxiety associated with SQ (r = -0.38, p = 0.008). - Present-state anxiety score: LSP > HSP After weight-loss program: **SQ and anthropometrics variables**: - BW loss: LSP = HSP (−3.5 ± 3.2 vs. −3.8 ± 2.8 kg) **SQ and satiety phenotype:** Changes in satiety efficiency: LSP =

					HSP (LSP pre 6.0 ± 2.6 vs. post 8.0 ± 5.4; HSP group pre 14.8 ± 3.5 vs. post 15.2 ± 4.4)
Hintze et al., 2019 [54]	n=36 <u>Slow weight loss</u>: n=17 Age=30.2±9.3 yr BMI= 32.1±3.1 kg/m² <u>Fast weight loss</u>: n=19 Age= 33.1±9.3 yr BMI= 34.0±4.4 kg/m²	Randomized trial <u>Intervention and duration</u>: 2 groups: - Slow weight loss (-500 kcal/day) during 20 weeks - Rapid weight loss (-1000 kcal/day) during 10 weeks <u>Assessment frequency</u>: baseline, 5-7 days after starting and post-intervention. <u>Assessments protocol</u>: standardized and personalized BF (ad libitum in preliminary session and replicated on subsequent sessions), ad	Fasting, at 0, 30,60,90,120,180 after standardized BF	SQ_H, SQ_{DTE} and SQ_{PFC} (mm/kcal)= (fasting rating - mean 60-min post-meal rating) /energy content of BF*100 SQ_F (mm/kcal)= (mean of the 60-min post-meal rating – fasting rating) /energy content of BF*100	Final sample: n=30, Slow weight loss: n=14, Fast weight loss: n=16 **<u>Other</u>:** - SQ_{DTE}, SQ_H and SQ_{PFC} at 60 and 180 min ↑ after the intervention.

		libitum lunch			
Beaulieu et al., 2020 [(59)]	n=46 CER: n=22 Age= 34.9±9 yr BMI= 28.9±2.3 kg/m² IER: n=24 Age= 35±11 yr BMI= 29.4±2.5 kg/m²	Randomized Control Trial Intervention and duration: 2 groups: - CER: Continuous Energy Restriction: 25% daily energy restriction during 12 weeks -IER: Intermittent Energy Restriction: alterning ad libitum meals and 75% energy restriction day during 12 weeks Assessment frequency: baseline and post-intervention. Assessments protocol: Body composition, individualized BF, ad libitum lunch, appetite sensation, eating behavior traits.	Before and after BF, BF+30, +60, +90, +120, +150 minutes, before and after lunch	SQ_H(mm/kcal)= (fasting rating - mean 180-min post-BF rating) /energy content of BF*100	Final sample per protocol (weight loss ≥5%): n=30 Baseline: - CER: n=18, Age= 35±9 yr BMI= 29.1±2.4 kg/m² - IER: n=12, Age= 34±10 yr BMI= 29.1±2.5 kg/m² After weight loss ≥5%: - CER: BMI= 27.3±2.3 kg/m² (≠ baseline p<0.001) - IER: BMI= 27.2±2.4 kg/m² (≠ baseline p<0.001) **SQ and anthropometrics variables**: No SQ ≠ between before and after weight-loss. **SQ, energy intake and appetite control:** No SQ ≠ between groups.

Protocol are detailed only the relevant of SQ; values are presented as means ± SD (standard deviation); AS: appetite sensation; EI: energy intake; BF: Breakfast; BW: Body Weight, NR: Not Reported. DTE: Desire To Eat; F: Fullness; H: Hunger, PFC: Prospective Food Consumption; S: Satiety; SQ: Satiety Quotient; LSP: Low Satiety Phenotype; HSP: High Satiety Phenotype.