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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 six 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, fifty-two were included. Of the studies included, thirty-three were acute studies (twenty-nine in adults and four in adolescents) and nineteen were longitudinal studies in adults. A high methodological heterogeneity in the application of the SQ was observed between studies. Five main utilisations of the SQ were identified: its association with (i) energy intake; (ii) anthropometric variables; (iii) energy expenditure/physical activity; (iv) sleep quality and quantity and (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 standardised use of the SQ in addition to further studies to investigate its validity in different contexts and populations, especially among children and adolescents.

Key words: Satiety Quotient: Appetite: Hunger: Fullness: Energy intake: Desire to eat: Prospective food consumption

According to the WHO, 39 % of adults were overweight and 13 % had obesity in 2016[1] with paediatric data being just as concerning with 340 million children from 5 to 19 years old classified with overweight and obesity worldwide[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 in recent years[4]. Both homoeostatic 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 scale; VAS). These VAS usually comprise 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 *et al.* 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

Abbreviations: 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; VAS, visual analogue scale.

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British Journal of Nutrition

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 utilised 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 the 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 is 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 sexes were included) and meal type (standardised 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 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 and 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 Fig. 1 illustrates the selection/inclusion/exclusion process. The initial database search

Table 1. Database search strategy details

Database	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.

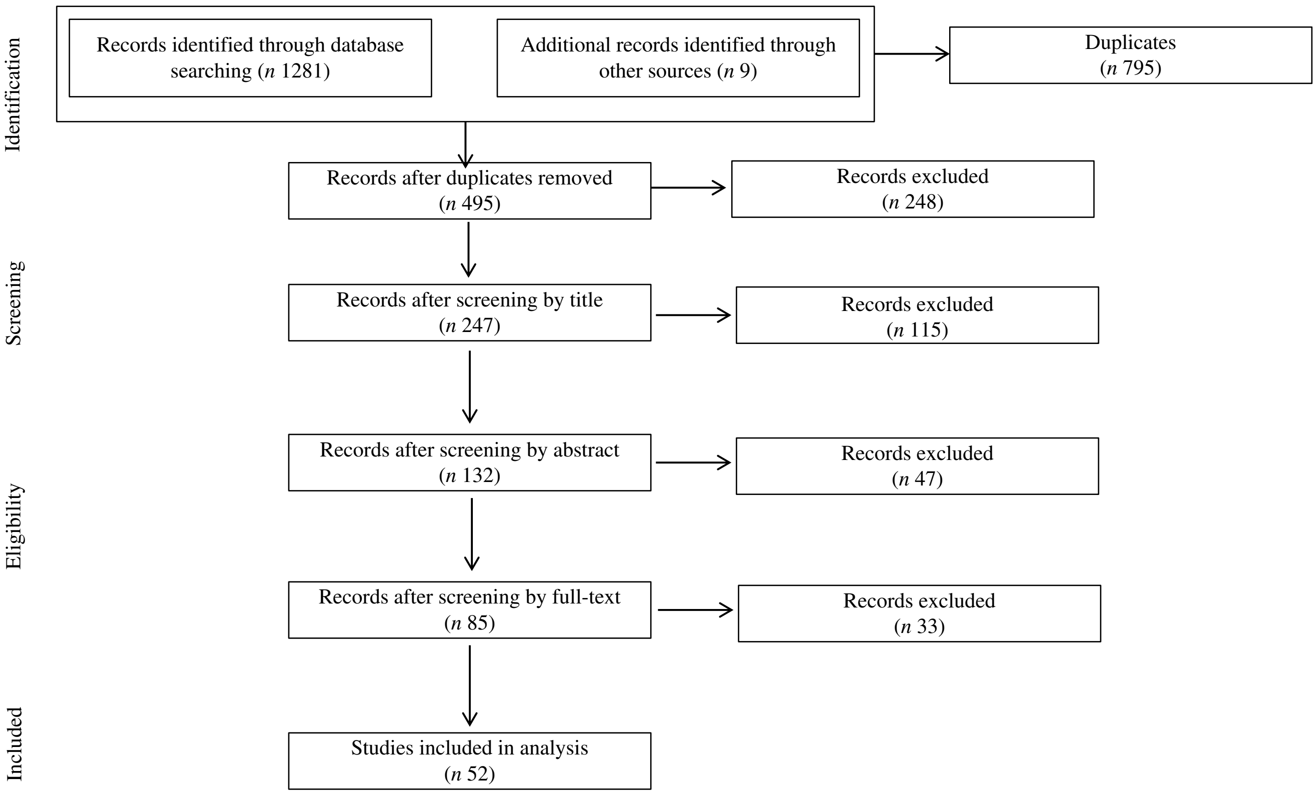

Fig. 1. Flow chart.

identified 1281 studies and nine 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 eighty-five full-text were screened, leaving fifty-two included studies. Table 2 details the risk of bias analysis. Of the fifty-two studies included, thirty-three were acute studies[6–8,11,13–15,18–42] and nineteen were longitudinal studies[9,10,12,43–59].

Acute studies

Of the thirty-three acute studies, twenty-nine were conducted in adults[6–8,11,13–15,18–37,40,43] and four 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 the online Supplementary material.

Methods

Topics. Of the twenty-nine studies, 90 % (*n* 26) compared SQ in response to a stimulus (meal, exercise and sleep), the remaining studies[8,13,14] used SQ to categorise 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 seventeen studies, two used liquid meals[28,33], fourteen solid meals[6,14,15,18,19,21,22,25,27,30,34–37,40] and one study compared solid *v* liquid meals[32]. Of these studies, three examined the effect of meals differing in energy content[14,28,33] and five 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 fibre and protein, and Au-Yeung *et al.*[30] compared the effect of different amounts of protein intake via konjac glucomannan capsules and one study examined the combined effects of a modification in macronutrients, unsaturated fats, fibre and Ca[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 four 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 with 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 twenty-eight studies investigated acute medication interventions[23,26] and one assessed the effect of hormone infusions[24]. Among the acute studies, two included acute exercise in their

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.*[38]	L	NR	L	M	L	L
Arguin *et al.*[40]	H	NR	NR	M	NR	L
Arguin *et al.*[12]	L	NR	NR	M	M	L
Au-Yeung *et al.*[30]	L	NR	NR	M	NR	L
Beaulieu *et al.*[25]	L	NR	NR	M	H	L
Beaulieu *et al.*[59]	L	NR	M	M	M	L
Bédard *et al.*[49]	H	NR	NR	M	L	L
Blanchet *et al.*[28]	L	NR	L	L	NR	L
Bligh *et al.*[21]	L	NR	L	M	H	L
Buckland *et al.*[58]	L	L	NR	M	L	L
Carbonneau *et al.*[52]	L	NR	NR	M	NR	L
Caudwell *et al.*[57]	H	NR	NR	M	L	NR
Chapman *et al.*[26]	L	L	L	M	L	NR
Chaput *et al.*[47]	H	NR	NR	M	L	L
Dalton *et al.*[14]	L	NR	NR	M	NR	L
Defries *et al.*[22]	L	NR	NR	H	NR	L
Drapeau *et al.*[8]	H	NR	L	M	NR	L
Drapeau *et al.*[10]	H	NR	M	M	L	L
Drapeau *et al.*[13]	H	NR	NR	L	H	NR
Drapeau *et al.*[53]	H	NR	NR	M	H	L
Dubé *et al.*[7]	L	NR	NR	M	NR	L
Felix *et al.*[32]	L	NR	NR	M	NR	NR
Felix *et al.*[36]	L	NR	NR	M	NR	NR
Fillon *et al.*[39]	L	NR	NR	M	L	L
Finlayson *et al.*[35]	L	NR	M	M	M	L
Gilbert *et al.*[48]	H	NR	M	M	L	L
Golloso-Gubat *et al.*[46]	L	NR	NR	M	L	NR
Gonzalez *et al.*[33]	M	NR	NR	M	NR	NR
Green *et al.*[6]	H	NR	NR	M	NR	NR
Halford *et al.*[56]	M	L	L	M	M	L
Hansen *et al.*[18]	L	NR	M	M	NR	L
Harrington *et al.*[43]	H	NR	NR	M	L	NR
Hintze *et al.*[54]	L	NR	NR	M	H	L
Hollingworth *et al.*[15]	L	NR	NR	NR	NR	NR
Hopkins *et al.*[19]	L	NR	NR	M	NR	NR
Jönsson *et al.*[44]	L	NR	NR	H	H	NR
Jönsson *et al.*[55]	L	NR	NR	H	L	L
Kral *et al.*[41]	L	L	M	L	L	L
Kendall *et al.*[34]	L	L	L	M	M	NR
King *et al.*[50]	H	NR	NR	M	L	NR
Martini *et al.*[27]	L	NR	NR	M	H	L
McNeil *et al.*[29]	H	NR	NR	M	NR	L
McNeil *et al.*[9]	H	NR	NR	H	H	L
McNeil *et al.*[31]	L	NR	NR	L	M	L
Polugrudov *et al.*[20]	L	NR	NR	M	NR	L
Rodríguez-Rodríguez *et al.*[45]	L	NR	H	H	L	NR
Salama *et al.*[11]	L	NR	L	M	H	L
Sanchez *et al.*[51]	L	L	L	M	H	NR
Schmidt *et al.*[24]	L	L	L	M	NR	NR
Thivel *et al.*[37]	L	NR	NR	M	NR	L
Thivel *et al.*[42]	L	NR	NR	M	L	L
Thomas *et al.*[23]	L	NR	L	M	M	L

L, low risk; M, medium risk; H, high risk; NR, not reported.

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] characterised the biopsychobehavioural profiles of men with low satiety phenotype at the start of a weight loss intervention.

Visual analogue scale. 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 three studies did not specify the type of scale used[15,19,25]. Of the twenty-three studies using pen and paper scales, fifteen used 100 mm scales[6,14,20,22,24,26,27,30–36,43], while eight used 150 mm scales[7,8,11,13,28,29,37,40]. For studies that used electronic VAS, one used 100 mm scales[18], one used 60 mm scales[21] and one did not specify the length of the scale used[23].

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The three 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 twenty-nine studies, twenty-eight assessed 'Hunger'[6–8,11,13–15,18–26,28–37,40,43], twenty-four measured 'Fullness'[7,8,11,13,14,18,20–31,33,34,36,37,40,43] and twenty 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 twenty studies[7,8,11,13–15,18,21–23,27–31,34,36,37,40,43] and 'Satiety' in four studies[18,20,24,27]. However, as described below, all appetite sensations measured were not used for the calculation of SQ.

Calculation of Satiety Quotient

Equations used. Of the twenty-nine acute studies included, eight used the initial equation proposed by Green *et al.*[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.*[10], 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.*[30] 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.*[23] 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)/energy consumed during quartile).

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], sixteen for 'Fullness'[7,8,11,13,20,21,24,27–29,31,34,36,37,40,43] and fifteen 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.*[13] also calculated a mean SQ with the SQ results corresponding to the four previous appetite sensations. In three 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 twenty-nine studies, twenty-three 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 six studies assessed pre-lunch sensations 1 h before the meal[26], 20 min before the meal[21] or 5 min 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, eight studies evaluated them up to 60 min after the end of food intake[7,8,13,23,28,29,33,37], five studies up to 120 min after the end of food intake[20,27,32,34,36], 4 up to 180 min after the end of food intake[18,22,25,31] and 3 up to 240 min after the end of food intake[6,11,40]. Hopkins *et al.*[19] reported appetite sensations every hour after the end of the meal until the next meal, while Chapman *et al.*[26] assessed appetite sensations up to 5 h after the end of the meal. Green *et al.*[6] measured appetite sensations up to 75 min after food intake, Schmidt *et al.*[24] reported post-meal appetite sensations up to 25 min after the meal and finally, Harrington *et al.*[43] reported post-meal appetite sensations immediately after the end of the meal. The study from Bligh *et al.*[21] reported appetite sensations up to 175 min after the start of food intake, while Dalton *et al.*[14] reported these sensations up to 90 min after the start of the meal. The timing of VAS is summarised in detail in Table 3.

Type of meal. Finally, SQ was also calculated in response to different meals. Among the included acute studies, thirteen used a standardised fixed meal to calculate SQ[7,8,13,21,22,28–30,32–34,36,37], while three used an individualised meal based on percentage of energy needs[14,31,35] and six used an *ad libitum* meal[20,23–26,43]. Six studies calculated the SQ on both types of meals: standardised 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 the Supplementary materials.

Methods

Calculation of Satiety Quotient. Three of the included studies used pen and paper VAS[38,39,42], and Kral *et al.* 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.* and Kral *et al.* used 100 mm scales[38,41]. Albert *et al.*[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].

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.*[6] Study 1	*n* 18 lean, healthy, dietary unrestrained men Age = NR BMI = NR	Cross-over study Protocol: standardised lunch, *ad libitum* snack Four 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 hours	SQ_H (mm/kJ) = (rating pre-eating standardised lunch – rating post-standardised lunch)/energy content of standardised lunch SQ calculated for each of the five post-lunch time points, subtracting the ≠ ratings from pre-meal rating	SQ, energy intake and appetite control: – No difference between conditions – Effect of time ($P < 0·001$) indicating that the lunches become less satiating per unit energy as time post-lunch ↑
Green *et al.*[6] Study 2	*n* 20 (twenty lean, healthy women, ten dietary restrained, ten dietary unrestrained) Age = NR BMI = NR	Cross-over study Protocol: standardised lunch, *ad libitum* snack, Four conditions: – Low-energy lunch (2238 kJ men, 1679 kJ women)/high-CHO snack – Low-energy lunch (2238 kJ 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	Pre-lunch, post-lunch, 13.30, 14.00, 14.30, 15.00 hours	Same SQ equation as Study 1 SQ calculated for each of the five 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 ($P < 0·05$)
Green *et al.*[6] Study 3	*n* 17 lean, healthy men Age = NR BMI = NR	Cross-over study Protocol: standardised preload, *ad libitum* meal Three 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 and 17.00 hours	Same SQ equation as Study 1 but for standardised preload SQ calculated for each of the five 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 hours.) – Effect of time ($P < 0·001$)
Green *et al.*[6] Study 4	*n* 16 lean, healthy men Age = NR BMI = NR	Cross-over study Protocol: standardised preload (yogurt), *ad libitum* meal Four preload conditions: – Low energy with aspartame (506 kJ) – Low energy without aspartame (506 kJ) – High energy with sucrose (1247 kJ) – High energy with maltodextrin (1167 kJ)	Pre-preload, 10, 20, 30, 40, 50 and 60 min post-preload	Same SQ equation as Study 1 but for standardised preload SQ calculated for each of the six post-meal time points, subtracting the ≠ ratings from pre-meal rating	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 ($P < 0·001$)
Green *et al.*[6] Study 5	*n* 10 men, 9 women Age = NR BMI = NR	Cross-over study Protocol: standardised BF, *ad libitum* lunch Four *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 seven 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 ($P = 0·01$)

Table 3. (*Continued*)

Study	Population characteristics	Design	VAS timing	SQ equation	Main results
Chapman *et al.*[26]	T2D: *n* 11 men Age = 60·2 (SD 8·5) years BMI = 28·9 (SD 4·8) kg/m^2 Obese without diabetes: *n* 15 men, Age = 41 (SD 21) years BMI = 34·4 (SD 4·5) kg/m²	Randomised, double-blind, placebo-controlled cross-over study Protocol: drug/placebo injection, standardised preload meal (189 kcal†), *ad libitum* buffet lunch Two conditions per group: – Pramlintide – Placebo	1 h before, immediately before and after the *ad libitum* lunch and 5 h after the beginning of the *ad libitum* lunch	1. Prandial SQ_H = (rating 1 h before *ad libitum* lunch – rating immediately after)/EI at the *ad libitum* lunch 2. Postprandial SQ_H = (rating 5 h after *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 ($P = 0·03$)) – 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.*[8]	Men: *n* 28 Age = 37·4 (SD 7·4) years BMI = 27·9 (SD 5·3) kg/m² Women: *n* 23 Age = 38·2 (SD 7·2) years BMI = 27·4 (SD 5·3) kg/m²	Observational study Protocol: standardised BF (733 kcal men, 599 kcal women), *ad libitum* lunch and dinner, TFEQ, body composition, metabolic rate Two groups: – Men – 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 1 h AUC (men+women: r 0·55, men: r 0·72, women: r 0·40, $P < 0·0001$) – SQ_F not related with any Three-Factor Eating Questionnaire 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, $P = 0·02$) Other: – Metabolic rate correlated with SQ_{DTE} (r –0·64, $P = 0·002$) and SQ_{PFC} (r –0·69, $P = 0·0005$)
Kendall *et al.*[34]	*n* 22 healthy subjects (thirteen men, nine women) Age = 26 (SD 4) years BMI = 23·7 (SD 2·4) kg/m²	Randomised cross-over controlled study Protocol: standardised cereal bar and beverage snack varying in dose of RS, *ad libitum* lunch Five beverage conditions: – 0 g RS (control) – 0 g RS (control) – 5 g RS – 10 g RS – 25 g RS	Before and at 15, 30, 45, 60, 90 and 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	Other: – SQ_F 5 g RS > SQ_F control 60-min after the test meal ($P < 0·04$) – For overall appetite score at 15, 30 and 45: SQ 25 g RS meal>control ($P = 0·1$, 0·08 and 0·04, respectively) – 25 g RS meal: the average appetite SQ over the 2 h post-meal time period was greater than control although this only approached significance ($P = 0·14$)

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Table 3. (*Continued*)

Study	Population characteristics	Design	VAS timing	SQ equation	Main results
Blanchet *et al.*[28]	*n* 153 premenopausal women P73T genotype (mutation in neuromedin-β gene): *n* 61 Age = 33·4 (SD 9·9) years BMI = 23·1 (SD 2·5) kg/m² P73P genotype (without mutation): *n* 85 Age = 33·3 (SD 10·4) years BMI = 22·7 (SD 2·7) kg/m² T73T genotype (with mutation): *n* 7 Age = 30·1 (SD 9·5) years BMI = 22·5 (SD 1·2) kg/m²	Randomised single-blind cross-over design Protocol: standardised dinner (day before), standardised BF, milkshake preloads at 10.00 hours, *ad libitum* cold buffet Two 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 standardised BF and preloads	Other: – No effect of genotype, meal (BF or preload) or interaction, for any of SQ
Finlayson *et al.*[35]	*n* 30 healthy women Age = 21·9 (SD 0·5) years BMI = 22·7 (SD 0·4) kg/m²	Randomised cross-over study Protocol: individualised preload (10 % of the estimated daily energy requirement; about 710–1050 kJ), *ad libitum* lunch (30 min after) Three preload conditions: – Sweet taste – Savoury 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 with lower scores
Arguin *et al.*[40]	*n* 18 men Age = 31·0 (SD 10·4) years BMI = 23·8 (SD 2·9) kg/m²	Controlled study Protocol: standardised BF (733 kcal), *ad libitum* lunch Three lunch conditions: – Control: *ad libitum* control macaroni + chocolate cake – Satiating: *ad libitum* macaroni containing more proteins, unsaturated fats, fibres and Ca 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 and 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 $SQ_{\text{-25 min}}$ (mm/kcal) = (pre-lunch rating – rating immediately after macaroni)/EI at lunch × 100 $SQ_{0\text{–}240\text{ min}}$ (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 $SQ_{\text{\_25 min}}$ DTE, H, S and PFC – $SQ_{DTE\_0\text{–}240}$ and $SQ_{H\_0\text{–}240}$, $SQ_{S\_120\text{–}240}$, $SQ_{PFC\_20\text{–}240}$: 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 $SQ_{\text{\_25min}}$) 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 ($SQ_{0\text{–}240\text{ min}}$) of the context effect meal > SQ control and the satiating meal ($SQ_{DTE\_0\text{–}240}$, $SQ_{H\_0\text{–}240}$, $SQ_{PFC\_0\text{–}240}$ and $SQ_{S\_120\text{–}240}$) (all $P \leq 0·05$) – Low restrained individuals SQ: context effect meal > SQ satiating meal (SQ_{PFC_180}, SQ_{H_240}, SQ_{PFC_240}) (all $P < 0·05$)

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Table 3. (*Continued*)

Study	Population characteristics	Design	VAS timing	SQ equation	Main results
Drapeau *et al.*[13]	*n* 69 men Age = 41·4 (SD 5·7) years BMI = 33·6 (SD 3·0) kg/m²	Observational study Protocol: standardised BF (733 kcal), Three-Factor Eating Questionnaire, body composition Two 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 LSP: mean SQ < 8 mm/100 kcal High satiety phenotype: mean SQ ≥ 8 mm/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 Three-Factor Eating Questionnaire 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 Other: – 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.*[7]	*n* 16 With T1D: *n* 12 (six men, six women) Age = 39·4 (SD 6·6) years BMI = 24·0 (SD 1·4) kg/m² With T2D: *n* 4 (three men, one women) Age = 53·3 (SD 2·8) years BMI = 25·5 (SD 1·4) kg/m²	Randomised cross-over controlled study Protocol: standardised BF (700 kcal men, 600 kcal women), exercise/rest, *ad libitum* lunch, self-reported 3-d energy intake (1–2 weeks before exercise) Three conditions: – Control: rest period 60 min – Exercise free (F): exercise 60 min on cycle ergometer at 50 % VO2peak with free blood glucose decrease – Exercise maintained (M): exercise 60 min on cycle ergometer at 50 % VO2peak with blood glucose maintained above 4 mmol/l	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 SQ, energy intake and appetite control: – Correlation between SQ_H and *ad libitum* EI (*r* –0·33, *P* ≤ 0·05) in T1D – Correlations between SQ_{DTE}, SQ_H, SQ_F and reported EI in T1D (*r* –0·43, –0·50, –0·36 and *P* ≤ 0·01, 0·01, 0·05, respectively) – 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.*[32]	*n* 10 (five men, five women) healthy adults Age range = 27–55 years BMI range = 20–25 kg/m²	Randomised cross-over study Protocol: standardised BF, *ad libitum* lunch Eight BF preload conditions (seven cooked rice varieties with 50 g available carbohydrate): – Improved Malagkit Sungsong 2 – Sinandomeng (low amylose content) – NSIC Rc160 (low amylose 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)	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 glycaemic index

Table 3. (*Continued*)

Study	Population characteristics	Design	VAS timing	SQ equation	Main results
Harrington *et al.*[43]	*n* 82 Men: *n* 40 Age = 26·4 (SD 4·0) years BMI = 23·5 (SD 2·5) kg/m² Women: *n* 42 Age = 26·9 (SD 4·7) years BMI = 22·4 (SD 2·0) kg/m²	Observational study Protocol: *ad libitum* lunch Three groups (tertiles of 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.*[29]	*n* 75 overweight/obese men Group 1 (Sleep duration) <7 h/night: *n* 34 Age = 41·6 (SD 6·6) years BMI = 33·5 (SD 2·9) kg/m² ≥7 h/night: *n* 41 Age = 40·4 (SD 4·6) years BMI = 33·8 (SD 3·0) kg/m² Group 2 (Sleep quality) PSQI score ≥5: *n* 33 Age = 41·0 (SD 6·4) years BMI = 33·4 (SD 2·9) kg/m² PSQI score <5: *n* 42 Age = 40·9 (SD 5) years BMI = 33·9 (SD 3·1) kg/m² Group 3 (Sleep timing) Midpoint of sleep > 02.30 hours: *n* 37 Age = 39·3 (SD 5·7) years BMI = 33·8 (SD 2·9) kg/m² Midpoint of sleep ≤ 02.30 hours: 38 Age = 41·8 (SD 5·0) years BMI = 33·8 (SD 3·2) kg/m²	Observational study Protocol: standardised BF (3066 kJ), *ad libitum* lunch Three groups: – Sleep duration – Sleep quality – Sleep timing	Before, immediately, after and every 10 min for 1 h after the standardised BF	SQ_H, SQ_F, SQ_{DTE}, SQ_{PFC} (mm/kcal) = (fasting rating –60 min post-BF)/energy content of BF × 100	SQ and sleep quality and quantity: – No difference in SQ_H, SQ_F, SQ_{DTE}, SQ_{PFC} between groups – Short-duration sleepers (<7 h/night) SQ2 < sleepers with recommended sleep duration (≥7 h/night) – Mean SQ sleep quality = mean SQ sleep timing
Schmidt *et al.*[24]	*n* 25 healthy males Age = 33 (SD 9) years BMI = 29 (SD 3) kg/m²	Randomised, double-blinded, placebo-controlled, four-arm cross-over study Protocol: standardised dinner day before, no BF, infusion, *ad libitum* lunch Four infusions: – GLP-1 – PYY3-36 – GLP-1 + PYY3-36 – 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)

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Table 3. (*Continued*)

Study	Population characteristics	Design	VAS timing	SQ equation	Main results
Thomas *et al.*[23]	Men: *n* 24 Placebo: *n* 8 Age = 20·8 (SD 0·4) years BMI = 23·8 (SD 0·7) 15 mg: *n* 8 Age = 21·9 (SD 0·8) years BMI = 22·1 (SD 0·7) 30 mg: *n* 8 Age = 20·4 (SD 0·5) years BMI = 22·8 (SD 0·8) Women: *n* 23 Placebo: *n* 8 Age = 22·4 (SD 1·0) years BMI = 21·5 (SD 0·7) 15 mg: *n* 8 Age = 20·4 (SD 0·5) years BMI = 22·0 (SD 0·8) 30 mg: *n* 8 Age = 19·9 (SD 0·7) years BMI = 22·4 (SD 0·9)	Randomised, double-blind, placebo-controlled study Protocol: typical BF, test dose (2 h before lunch), *ad libitum* lunch Three test doses: – Placebo – 5-HT2C receptor agonist meta-chlorophenylpiperazine (mCPP) 15 mg – mCPP 30 mg	4 h pre-lunch, 2 h pre-lunch and every 30 min, during lunch, post-lunch, 1 h post-lunch	SQ_H = ((quartile initial rating – quartile ending rating)/energy content consumed at *ad libitum* lunch during quartile) Note: the authors define SQ as 'Satiation Quotient'	Other: – Effect of quartile ($P < 0·001$) and sex ($P < 0·05$), a two-way interaction between sex and condition ($P < 0·01$) and a three-way interaction between quartile, sex 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 2–3 ($P < 0·05$) 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.*[21]	*n* 21 healthy males Paleolithic-type meal 1: *n* 17 Age = 27·9 (SD 13·2) years BMI = 23·4 (SD 2·7) kg/m² Paleolithic-type meal 2: *n* 19 Age = 27·5 (SD 12·7) years BMI = 23·4 (SD 2·6) kg/m² Reference meal: *n* 19 Age = 27·5 (SD 12·7) years BMI = 23·4 (SD 2·6) kg/m²	Randomised cross-over study Three standardised 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 normalised 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.*[14]	*n* 30 women Age = 28·0 (SD 10·6) years BMI = 23·1 (SD 2·9) kg/m²	Randomised cross-over study Protocol: individualised and calibrated BF, *ad libitum* lunch, Four BF conditions: – Calibrated to 20 % 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 three out of four conditions (*n* 9) whereas the high satiety phenotypes were identified as those who had a high SQ at least three out of four 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 Three-Factor Eating Questionnaire 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 with the high satiety phenotype ($P < 0·001$)

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Table 3. (*Continued*)

Study	Population characteristics	Design	VAS timing	SQ equation	Main results
Felix *et al.*[36]	*n* 12 healthy subjects (seven men, five women) Age range = 20–50 years BMI range = 20–25 kg/m²	Randomised, cross-over study Protocol: standardised preload, *ad libitum* lunch Nine preload conditions: – Milled rice: IMS2 – Milled rice: NSIC Rc160 – Milled rice: IR64 – Milled rice: PSB Rc10 – Brown rice: IMS2 – Brown rice: NSIC Rc160 – Brown rice: IR64 – Brown rice: PSB Rc10 – Reference food: 240 ml standard glucose drink	Before preload and every 15 min during the 1st hour and every 30 min during the 2nd hour after preload	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 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 glycaemic index 2 h post-meal: – The higher SQ for brown rice than milled rice was not translated into lower common cooked rice intake
Hopkins *et al.*[19]	*n* 65 (twenty-six men, thirty-nine women) Age = 41·3 (SD 8·7) years BMI = 30·90 (SD 3·8) kg/m²	Randomised cross-over study Protocol: *ad libitum* BF, standardised lunch (800 kcal), *ad libitum* dinner, *ad libitum* snack box Two meal conditions: – High-fat/low-carbohydrate day: high-fat/low-carbohydrate for all meals – Low-fat/high-carbohydrate day: low-fat/high-carbohydrate for all meals	Immediately before and after a meal and at hourly intervals throughout the day (from 08.00 to 18.00 hours)	SQ_H (mm/kcal) = (rating pre-eating episode – rating post-eating episode)/intake of eating episode × 100 SQ calculated for BF and lunch	SQ, energy intake and appetite control: SQ low-fat/high-carbohydrate > SQ high-fat/low-carbohydrate after BF and lunch (P = 0·006 and P = 0·001, respectively)
Salama *et al.*[11]	*n* 35 healthy adults Men: *n* 18 Age = 25·4 (SD 3·6) years BMI = 23·6 (SD 2·1) kg/m² Women: *n* 13 Age = 22·6 (SD 3·3) years BMI = 22·5 (SD 2·1) kg/m²	Randomised cross-over study Protocol: standardised BF (men 715 kcal, women 599 kcal) mental work/control, *ad libitum* buffet lunch, waist circumference, body composition Two conditions (during 45 min): – 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 h	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.*[25]	*n* 39 non-obese adults High levels of physical activity: *n* 20 (ten men, ten women) Age = 29·9 (SD 9·6) years BMI = 22·6 (SD 1·9) kg/m² Low levels of physical activity: *n* 19 (eight men, eleven women), Age = 30·4 (SD 9·3) years BMI = 23·1 (SD 2·7) kg/m²	Randomised cross-over study Protocol: individualised BF (*ad libitum* on first test day standardised to quantities consumed on second test day), *ad libitum* lunch Two lunch conditions – HFAT: high-fat *ad libitum* lunch – HCHO: high-carbohydrate *ad libitum* lunch	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

Table 3. (*Continued*)

Study	Population characteristics	Design	VAS timing	SQ equation	Main results
Defries *et al.*[22] Seed study	*n* 38 (ten men, twenty-eight women) Age = 37·7 years (range 20–67) BMI = 24·8 kg/m² (range 18·7–30·4)	Single-site, randomised, controlled, cross-over study Protocol: typical BF (replicated on subsequent test days), standardised snack food, *ad libitum* lunch, food diary remainder of day Two snack conditions (140 kcal): – Roasted buckwheat groats – Maize nuts (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	SQ, energy intake and appetite control: – Effect of time for SQ buckwheat groats ($P < 0{\cdot}0001$)
Defries *et al.*[22] Pita study	*n* 38 (eleven men, twenty-seven women) Age = 33·5 years (range 20–67) BMI = 24·4 kg/m² (range 18·7–30·4)	Single-site, randomised, controlled, cross-over study Protocol: individualised BF, standardised snack food, *ad libitum* lunch, food diary remainder of day Two snack conditions (about 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	SQ, energy intake and appetite control: – Effect of time ($P < 0{\cdot}0001$) and snack ($P = 0{\cdot}0002$) for the SQ buckwheat pita (SQ buckwheat pita > SQ rice bread)
Gonzalez *et al.*[33]	Experiment 1: *n* 10 non-obese men Age = 22 (SD 1) years BMI = 24·8 (SD 1·6) kg/m² Experiment 2: *n* 10 non-obese men Age = 21 (SD 4) years BMI = 24·2 (SD 2·3) kg/m²	Randomised, double-blind, cross-over study (data from two experiments pooled for analyses) Protocol: liquid meal Experiment 1: two liquid meal conditions (repeated twice) – Low energy: 579 kJ – Moderate energy: 1776 kJ Experiment 2: two liquid meal conditions (repeated twice) – Low energy: 828 kJ – High energy: 4188 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 calculated with (hunger, (100-fullness), satisfaction and PFC)/4	SQ, energy intake and appetite control: The reproducibility of the SQ is better in response to the ingestion of meals of higher energy content compared with lower energy meals
McNeil *et al.*[31]	*n* 18 (twelve men, six women) Age = 23 (SD 4) years BMI = 22·7 (SD 2·7) kg/m²	Randomised cross-over study Protocol: individualised BF (*ad libitum* on preliminary session and standardised to quantities consumed on subsequent sessions) *ad libitum* lunch Three 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 and 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	SQ and sleep quality and quantity: – No difference in SQ between sessions – No correlations between changes in sleep stage durations with mean SQ between sessions

Table 3. (*Continued*)

Study	Population characteristics	Design	VAS timing	SQ equation	Main results
Polugrudov *et al.*[20]	*n* 66 SJL ≤1 h: *n* 17 (three men, fourteen women), Age = 23·7 (SD 2·9) years BMI = 21·2 (SD 2·5) kg/m² SJL 1 h to ≤2 h: *n* 28 (ten men, eighteen women) Age = 22·8 (SD 3·2) years BMI = 22·2 (SD 3·2) kg/m² SJL > 2 h: *n* 21 (six men, fifteen women) Age = 23·2 (SD 4·1) years BMI = 23·4 (SD 4·6) kg/m²	Randomised trial Protocol: *ad libitum* BF Three groups: – SJL ≤ 1 h – SJL 1 h 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 1–2 h and SJL > 2 h groups lower than SJL ≤ 1 h group ($P < 0·01$)
Au-Yeung *et al.*[30]	*n* 16 (four men, twelve women) Age = 26 (SD 19) years (range 18–62), BMI = 23·1 (SD 3·2) kg/m²	Randomised, single-blind, controlled, dose–response cross-over study Protocol: standardised preload, *ad libitum* dessert Three 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	SQ, energy intake and appetite control: 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.*[18]	*n* 39 (eleven men, twenty-eight women) Age = 26·3 (SD 10·9) years BMI = 24·4 (SD 3·1) kg/m²	Double-blind randomised cross-over study Protocol: standardised BF, *ad libitum* meal Three BF conditions (including 80 g cheese): – HP/LF: high-protein/low-fat hard cheese (1721 kJ) – HP/HF: high-protein/high-fat hard cheese (2000 kJ) – LP/HF: low-protein/high-fat cream cheese (1796 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 meal	Composite SQ (mm/kJ) = (pre-meal rating – post-meal rating) × 100/EI of the food consumed Composite SQ calculated with (satiety + fullness + (100-hunger) + (100-DTE) + (100-PFC)/5 SQ calculated at BF and lunch Note: the authors define SQ as 'Appetite Quotient'	SQ, energy intake and appetite control: – ↑ 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
Hollingworth *et al.*[15]	*n* 42 females Age = 26·0 (SD 7·9) years BMI = 22·0 (SD 2·0) kg/m²	Randomised cross-over study Protocol: mid-morning snack, *ad libitum* EI Three snack conditions: – Raw almonds – Savoury 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 PFC: low SQ > high SQ – Satiating efficiency in low SQ: almonds > snack (crackers) – Low SQ = behavioural and psychological characteristics associated with risk for overconsumption (but substitution of certain snack foods may improve the satiety responsiveness of these individuals)

Table 3. (*Continued*)

Study	Population characteristics	Design	VAS timing	SQ equation	Main results
Martini *et al.*[27]	*n* 20 females Age = NR BMI = <25 kg/m²	Randomised cross-over study Protocol: own low-fibre BF, standardised lunch, *ad libitum* snack Five pasta lunch conditions: – High fibre – High fibre + high protein – High protein (soya 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	SQ, energy intake and appetite control: – SQ_F for all formulations > SQ_F control pasta immediately after lunch and over the subsequent 2 h – SQ_{DTE} for high fibre + high protein pasta < SQ_{DTE} for control pasta after lunch and after snack consumption – Only high fibre pasta showed a higher SQ_S compared with control
Thivel *et al.*[37]	*n* 19 normal weight (ten men, nine women) Age = 21 (SD 1) years BMI = 22·3 (SD 2·9) kg/m²	Randomised controlled cross-over study Protocol: standardised BF (500 kcal), exercise/control, standardised lunch (women: 750 kcal, men: 900 kcal) Three conditions: – CON: rest during 45 min – LIE: 45 min cycling at 50 % VO2max – HIE: 30 min cycling at 75 % VO2max	Before and after BF, before and after exercise/rest, before and after lunch and 30 min and 60 min after the test meal	SQ_H, SQ_F, SQ_{DTE}, SQ_{PFC} (mm/kcal) = (pre-meal rating – mean 60 min post-meal rating)/energy content of lunch × 100	SQ, physical activity and energy expenditure: – 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 and HIE) – SQ_{PFC} HIE < CON ($P = 0·02$) (no difference between CON and LIE and HIE)

VAS, visual analogue scale; SQ, Satiety Quotient; NR, not reported; AS, appetite sensation; H, hunger; BF, breakfast; EI, energy intake; T2D, type 2 diabetes; BW, body weight; F, fullness; DTE, desire to eat; PFC, prospective food consumption; S, satiety; RS, resistant starch; LSP, low satiety phenotype; T1D, type 1 diabetes; AREE, activity-related energy expenditure; SJL, social jetlag; LIE, low-intensity exercise; HIE, high-intensity exercise.
* Only protocol is detailed that is relevant to SQ.
† To convert energy values from kcal to kJ, multiply by 4·184.

Regarding the calculation of SQ, all of the included studies used the equation proposed by Drapeau *et al.*[10] (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 min and 60 min post-meal in Thivel *et al.* and Fillon *et al.*'s studies[39,42] and immediately post-meal and 15 min 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 the Supplementary materials.

Methods

Topics. Eighty-four percentage 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- *v.* post-menopause in women)[9,10,44–52,54–57,59], while three of these nineteen 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, seven assessed the effect of different dietary prescriptions on SQ[12,44–46,55,58,59], while two 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.*[52] the effect of different nutritional labelling. Finally, the effect of probiotic[51] or pharmaceutical[56] compounds on the change of SQ was also tested.

Visual analogue scale. Fifteen studies used pen and paper VAS[9,10,12,45–49,51–54,56,58,59], while the other four used electronic VAS. Of the fifteen that used the pen and paper method, six 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 regard to electronic VAS, one study used a seven-point scale[44], another used a scale ranging from –3 to 3[55] and finally, two studies did not specify the length of the scales used[50,57].

Sixteen of the nineteen studies analysed 'Hunger'[9,10,12,45–54,56,57,59] and fifteen 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 twelve 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 Satiety Quotient

Equations used. Seventy-four percentage 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.*[58] used the same equation, but they subtracted post-meal sensation from pre-meal sensation, because they evaluated just 'Fullness'. Hintze *et al.*[54] 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. 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 nineteen chronic studies, fifteen calculated SQ_H[9,10,12,45–48,50–54,56,57,59], fourteen SQ_F[9,10,12,44,47–49,51–56,58] and nine 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', five studies used only the sensations immediately after the meal[45,47–49,52], and two studies considered the post-meal sensations as the sensations recorded 30 min after the start of ingestion[44,55]. Others averaged appetite sensations immediately after eating with appetite sensations 1 h after eating[57], or every 10 min for 1 h[10,51,53], or every 10 min for 1 h plus 90 min and 120 min after eating[12]. Three studies used the average appetite sensation immediately after eating with the sensations reported every 30 min for 3 h[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 h and not every 30 min. Finally, Golloso-Gubat *et al.*[46] used the average of appetite sensation at 15, 30, 45, 60, 90, 120, 150, 180 and 240 min 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 two meals (Table 5).

Type of meal. Out of the nineteen included studies, seventeen calculated the SQ in response to a standardised fixed meal[9,10,12,46,48,51,53], while five 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 individualised 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 3–5, five main methodological uses of the SQ can be identified: (i) the

Table 4. Data detailed for children and adolescents acute studies

Study	Population characteristics	Design	VAS timing	SQ equation	Main results
Albert *et al.*[38]	*n* 12 boys Age = 17 (SD 1·6) years BMI = 23·1 (SD 3·1) kg/m²	Randomised cross-over study Protocol: standardised BF, exercise (70 % VO_{2max}), *ad libitum* lunch (12.00 hours), *ad libitum* dinner (17.00 hours) Two conditions: – ExMeal: exercise at 11.15 hours, meal at 12.00 hours – Ex_{delay}Meal: exercise at 09.00 hours, meal at 12.00 hours	Before and after lunch and dinner	SQ_H (mm/kJ) = (pre-lunch rating – post-lunch rating)/ EI at lunch × 100	SQ, physical activity and energy expenditure: – No difference SQ between conditions at lunch and dinner
Fillon *et al.*[39]	*n* 15 (six boys and nine girls) Age = 13·1 (SD 1·4) years BMI = 34·7 (SD 6·0) kg/m² (*z*-BMI 2·3 (SD 0·3))	Randomised controlled study Protocol: standardised BF, exercise/rest condition, *ad libitum* lunch (12.00 hours), *ad libitum* dinner (18.00 hours) Three conditions: – Rest condition (CON) – 30-min exercise (65 % VO_{2max}) 180 min before lunch (EX-180) – 30-min exercise (65 % VO_{2max}) 30 min before lunch (EX-30)	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: – SQ_H CON < SQ_H EX180 and EX30 – SQ_{PFC} CON < SQ_{PFC} EX180 and EX30 – SQ_{DTE} CON < SQ_{DTE} EX180 and EX30
Kral *et al.*[41]	*n* 212 LR-NW: *n* 60 (twenty-eight boys and thirty-two girls) Age = 8·3 (SD 0·7) years *z*-BMI = –0·2 (SD 0·7) HR-NW: *n* 77 (twenty-nine boys and forty-eight girls) Age = 8·3 (SD 0·8) years *z*-BMI = 0·2 (SD 0·6) HR-OB: *n* 75 (twenty-nine boys and forty-six girls) Age = 8·5 (SD 0·8) years *z*-BMI = 1·7 (SD 0·5)	Randomised cross-over study Protocol: standardised preload, *ad libitum* BF (09.00 hours), *ad libitum* lunch (12.00 hours), *ad libitum* dinner (16.30 hours), snack Two conditions: – LED: low energy density preload (100 g, 100 kcal) – HED: high energy density preload (100 g, 160 kcal) Three 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 children with high risk for obesity	Before and after preload and BF, 60, 120 and 180 min 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 ($P > 0·10$)
Thivel *et al.*[42]	*n* 14 (six boys, eight girls) Age = 12·8 (SD 0·9) years BMI = 34·8 (SD 5·7) kg/m² (*z*-BMI 2·3 (SD 0·4))	Randomised controlled study Protocol: standardised BF, exercise/rest condition, *ad libitum* lunch (12.00 hours), *ad libitum* dinner (18.00 hours) Three 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}

VAS, visual analogue scale; SQ, Satiety Quotient; BF, breakfast; H, hunger; EI, energy intake; S, satiety; DTE, desire to eat; F, fullness; PFC, prospective food consumption; LED, low energy density; HED, high energy density.
* To convert energy values from kcal to kJ, multiply by 4·184.

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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.*[47]	*n* 11 men Age = 38 (SD 16·6) years BMI = 33·4 (SD 3) kg/m²	Interventional study Duration: after a 10 (SD 1) kg BW loss was achieved Intervention: diet and exercise Assessment frequency: baseline, after 5 (SD 1) kg BW loss (Phase 1) and after 10 (SD 1) kg BW loss (Phase 2) Assessment protocol: anthropometric measurements, standardised 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	SQ and anthropometrics variables: – No difference in SQ between phases
Drapeau *et al.*[10]	*n* 253 Men: *n* 142 Age = 42·7 (SD 7·15) years BMI = 32·5 (SD 3·6) kg/m² Women: *n* 111 Age = 41·3 (SD 7·4) years BMI = 33·7 (SD 3·2) kg/m²	Observational study Subjects were selected from different weight loss studies (data pooled for analyses) Study 1: Duration: 1 year, 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 + Ca and vitamin D/placebo Study 6: Duration: 15 weeks, Intervention: Diet + micronutrient supplementation/placebo Assessment frequency: baseline and post-intervention Assessment protocol: anthropometrics, standardised BF (men 733 kcal, women 599 kcal), *ad libitum* lunch, self-reported energy intake	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 of BF × 100	Baseline data: SQ, energy intake and appetite control: – SQ_{F} was correlated – with *ad libitum* EI (r –0·14, $P < 0·05$) (just in women (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, $P < 0·01$)
Rodríguez-Rodríguez *et al.*[45]	*n* 57 women, age = 27·8 (SD 4·7) years Diet V: *n* 28 BMI = 27·6 (SD 2·5) kg/m² Diet C: *n* 29 BMI = 28·3 (SD 3·4) kg/m²	Randomised study Duration: 6 weeks Intervention: two 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, standardised 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.*[48]	*n* 54 women Age = 39·9 (SD 7·5) years BMI = 32·9 (SD 3·5) kg/m²	Interventional study Duration: 4 or 6 months Intervention: energy restriction programme (2900 kJ/d) Assessment frequency: Baseline and post-intervention Assessment protocol: Anthropometrics, standardised BF (2504 kJ)	Before and after BF, 1 h 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

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Table 5. (*Continued*)

Study	Population characteristics at baseline	Design	VAS timing	SQ equation	Main results
King *et al.*[50]	*n* 58 (19 men, 39 women) Age = 39·6 (SD 9·8) years BMI = 31·8 (SD 4·5) kg/m²	Interventional study Duration: 12 weeks Intervention: exercise programme (500 kcal per session, 70 % of individual's maximum heart rate 5 d/week) Assessment frequency: baseline and post-intervention Assessment protocol: anthropometrics, individualised BF (*ad libitum* at baseline and quantities replicated post-intervention; 406 (SD 5) kcal), *ad libitum* lunch and dinner, evening snack box	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 standardised BF ↑ over the 12-week period of exercise. This effect was maintained for 4 h after the meal
Halford *et al.*[56]	*n* 30 women Age = 46·0 (SD 12·9) years BMI = 34·6 (SD 3·3) kg/m²	Double-blind, placebo-controlled crossover study Duration: 7 d Intervention: three conditions: – Sibutramine 10 mg per d – Sibutramine 15 mg per d – Placebo Assessment frequency: before and after drug administration (7 d) Assessment protocol: standardised BF (2173 kJ), *ad libitum* lunch	Before and after BF, 10.00, 11.00, 12.00 hours, before and after lunch at 13.00, 15.00, 16.00, 17.00 hours	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.*[44]	*n* 29 men ischaemic heart disease patients with impaired glucose tolerance or T2D and waist circumference >94 cm Age = NR BMI = NR	Interventional randomised study Duration: 12 weeks Intervention: two 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 MUFA and α-linolenic acid Assessment frequency: measured once at 15 (SD 5) d Assessment protocol: 4-d 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 seven-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), glycaemic load (*r* 0·50, *P* = 0·007), SFA (*r* 0·41, *P* = 0·03) and Na (*r* 0·51, *P* = 0·007)
Caudwell *et al.*[57]	*n* 107 adults with overweight/obesity Men: *n* 35 Age = 41·3 (SD 8·6) years BMI = 30·5 (SD 8·6) kg/m² Premenopausal women: *n* 72 Age = 40·6 (SD 9·5) years BMI = 31·8 (SD 4·3) kg/m²	Interventional study Duration: 12 weeks Intervention: aerobic exercise (500 kcal per session, 70 % of individual's maximum heart rate 5 d/week) Assessment frequency: baseline and post-intervention Assessment protocol: anthropometric measurements, individualised standardised-energy BF, standardised 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 programme ↑ 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

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Table 5. (*Continued*)

Study	Population characteristics at baseline	Design	VAS timing	SQ equation	Main results
Jönsson *et al.*[55]	*n* 13 (ten men, three women) T2D Age = NR BMI = NR	Randomised cross-over study Duration: 3 months Intervention: two conditions: – Diabetes diet (current guidelines) – Paleolithic diet Assessment frequency: baseline and after 3 (in-between crossover) and 6 months Assessment protocol: 4-d weighed food record at 6 weeks	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), glycaemic load (rating/kg) and glycaemic 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)	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 glycaemic index per meal – SQ for energy per meal correlated with TAG levels and vitamin B_6 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 glycaemic load correlated with BMI and spirits (r= –0·84 and 0·59, $P = 0·0003$ and 0·03, respectively)
McNeil *et al.*[9]	*n* 102 premenopausal women Age = 49·9 (SD 1·9) years BMI = 23·3 (SD 2·2) kg/m²	Observational study Duration: 5 years Assessment frequency: baseline and every 1 year Assessment protocol: anthropometric measurements, standardised BF (575 kcal), *ad libitum* lunch, 7-d food diary	VAS: before, immediately after and every 30 min for 3 h 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-d 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

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Table 5. (*Continued*)

Study	Population characteristics at baseline	Design	VAS timing	SQ equation	Main results
Bédard *et al.*[49]	*n* 70 Men: *n* 38 Age = 42·6 (SD 7·4) years BMI = 29·0 (SD 3·1) kg/m² Premenopausal women: *n* 32 Age = 41·2 (SD 7·4) years BMI = 29·6 (SD 5·6) kg/m²	Interventional study Duration: 16 weeks Intervention: isoenergetic MedDiet standardised and personalised menu (assessment frequency: every Wednesday from week 1 to 4 Assessment protocol: individualised 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.*[52]	*n* 141 Low-fat label normal weight: *n* 23 Age = 43·5 (SD 10·8) years BMI = 22·4 (SD 1·6) kg/m² Low-fat label obese: *n* 23 Age = 52·3 (SD 11·5) years BMI = 34·7 (SD 3·9) kg/m² Energy label normal weight: *n* 25 Age = 37·7 (SD 12·6) years BMI = 21·8 (SD 1·9) kg/m² Energy label obese: *n* 23 Age = 46·0 (SD 14·3) years BMI = 34·5 (SD 4·9) kg/m² No label normal weight: *n* 22 Age = 42·6 (SD 12·4) years BMI = 22·8 (SD 1·5) kg/m² No label obese: *n* 25 Age = 53·0 (SD 11·0) years BMI = 32·6 (SD 2·3) kg/m²	Randomised controlled trial Duration: 10 d Intervention: three meals per d under *ad libitum* conditions Three 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 Assessment 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)
Golloso-Gubat *et al.*[46]	*n* 34 healthy male adults Age = 27·7 (SD 6·2) years BMI = 22·1 (SD 1·9) kg/m²	Randomised crossover study Duration: 6 weeks Intervention: three conditions: – BF with brown rice – BF with white rice – Control Assessment frequency: before and after each condition Assessment protocol: standardised BF (500 kcal; including 160 g cooked rice)	Before, and 15, 30, 45, 60, 90, 120, 150, 180 and 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)

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Table 5. (*Continued*)

Study	Population characteristics at baseline	Design	VAS timing	SQ equation	Main results
Arguin *et al.*[12]	*n* 69 men Control diet LSP: *n* 15 Age = 41·0 (SD 6·3) years BMI = 34·1 (SD 3·5) kg/m² Control diet HSP: *n* 19 Age = 41·9 (SD 5·5) years BMI = 33·9 (SD 2·8) kg/m² Satiating diet LSP: *n* 17 Age = 40·4 (SD 6·2) years BMI = 33·6 (SD 3·0) kg/m² Satiating diet HSP: *n* 18 Age = 42·55 (SD 5·0) years BMI = 32·9 (SD 2·9) kg/m²	Randomised controlled trial Duration: 16 weeks Intervention: Diet intervention Two 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 Assessment protocol: anthropometrics, standardised BF (733 kcal), Three-Factor Eating Questionnaire	Before, immediately after and at 10 min intervals until 1 h 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 < 8 mm/100 kcal High satiety phenotype: mean SQ ≥ 8 mm/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
Sanchez *et al.*[51]	*n* 125 Probiotic group: *n* 62 Age = 35·0 (SD 10·0) years BMI = 33·8 (SD 3·3) kg/m² Placebo: *n* 63 Age = 37·0 (SD 10·0) years BMI = 33·3 (SD 3·2) kg/m²	Double-blind, randomised, placebo-controlled study Duration: 24 weeks Intervention: 12-week moderate energy restriction including two daily capsules of probiotic/placebo (Phase 1), followed by 12 weeks of weight maintenance (Phase 2) Assessment frequency: baseline, week 12, week 24 Assessment protocol: anthropometrics, standardised BF (men 733 kcal, women 599 kcal), *ad libitum* lunch, Three-Factor Eating Questionnaire	Before, immediately after, and every 10 min for 1 h after the standardised 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	Other: – 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.*[58]	*n* 52 women Age = 41·2 (SD 12·5) years BMI = 34·0 (SD 3·6) kg/m²	Randomised controlled trial Duration: 14 weeks Intervention: weight loss programme with low energy density meal and high energy density meal at week 3 and 12 Assessment frequency: week 3 and 12 Assessment protocol: anthropometric measurements, Three-Factor Eating Questionnaire, craving control, food reward, low energy density and high energy density test days: individualised 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 < 4·5 mm/100 kcal High satiety phenotype: SQ ≥ 8·5 mm/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 programme adherence: LSP < HSP

Table 5. (*Continued*)

Study	Population characteristics at baseline	Design	VAS timing	SQ equation	Main results
Drapeau *et al.*[53]	*n* 100 Low satiety responsiveness: *n* 50 (23 men, 27 women) Age = 37·8 (SD 9·5) years BMI = 33·7 (SD 3·9) kg/m² High satiety responsiveness: *n* 50 (six men, forty-four women) Age = 39·6 (SD 7·8) years BMI = 32·6 (SD 3·3) kg/m²	Observational study Subjects were selected from different weight loss studies Studies 1 and 2: Duration: 15 weeks, intervention: energetic restriction (–700 kcal/d) Study 3: Duration: 12 weeks, intervention: energetic restriction (–500 kcal/d) Assessment frequency: Baseline and post-intervention Assessment protocol: Anthropometrics, standardised BF (men 733 kcal, women 599 kcal), *ad libitum* lunch, Three-Factor Eating Questionnaire, 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 < 8 mm/100 kcal High satiety phenotype: mean SQ ≥ 8 mm/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 with 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 programme: SQ and anthropometrics variables: – BW loss: LSP = HSP (–3·5 (SD 3·2) *v.* –3·8 (SD 2·8) kg) SQ and satiety phenotype: Changes in satiety efficiency: LSP = HSP (LSP pre 6·0 (SD 2·6) *v.* post 8·0 (SD 5·4); HSP group pre 14·8 (SD 3·5) *v.* post 15·2 (SD 4·4))
Hintze *et al.*[54]	*n* 36 Slow weight loss: *n* 17 Age = 30·2 (SD 9·3) years BMI = 32·1 (SD 3·1) kg/m² Fast weight loss: *n* 19 Age = 33·1 (SD 9·3) years BMI = 34·0 (SD 4·4) kg/m²	Randomised trial Intervention and duration: Two groups: – Slow weight loss (–500 kcal/d) during 20 weeks – Rapid weight loss (–1000 kcal/d) during 10 weeks Assessment frequency: baseline, 5–7 d after starting and post-intervention Assessment protocol: standardised and personalised BF (*ad libitum* in preliminary session and replicated on subsequent sessions), *ad libitum* lunch	Fasting, at 0, 30, 60, 90, 120, 180 after standardised 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 Other: – SQ_{DTE}, SQ_H and SQ_{PFC} at 60 and 180 min ↑ after the intervention
Beaulieu *et al.*[59]s	*n* 46 CER: *n* 22 Age = 34·9 (SD 9) years BMI = 28·9 (SD 2·3) kg/m² IER: *n* 24 Age = 35 (SD 11) years BMI = 29·4 (SD 2·5) kg/m²	Randomised controlled trial Intervention and duration: Two groups: – CER: 25 % daily energy restriction during 12 weeks – IER: alterning *ad libitum* meals and 75 % energy restriction day during 12 weeks Assessment frequency: baseline and post-intervention Assessment protocol: body composition, individualised BF, *ad libitum* lunch, appetite sensation, eating behaviour traits	Before and after BF, BF +30, +60, +90, +120, +150 min, 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 (SD 9) years BMI = 29·1 (SD 2·4) kg/m² – IER: *n* 12, age = 34 (SD 10) years BMI = 29·1 (SD 2·5) kg/m² After weight loss ≥5 %: – CER: BMI = 27·3 (SD 2·3) kg/m² (≠ baseline *P* < 0·001) – IER: BMI = 27·2 (SD 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

VAS, visual analogue scale; SQ, Satiety Quotient; BW, body weight; BF, breakfast; H, hunger; F, fullness; DTE, desire to eat; PFC, prospective food consumption; EI, energy intake; T2D, type 2 diabetes; NR, not reported; S, satiety; RS, resistant starch; LSP, low satiety phenotype; HSP, high satiety phenotype; CER, continuous energy restriction; IER, intermittent energy restriction.

* Only protocol is detailed that is relevant to SQ.

† To convert energy values from kcal to kJ, multiply by 4·184.

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association between SQ and EI[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] and (v) SQ to classify individuals into low and high satiety phenotypes[13–15,40,53,58].

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

Association between Satiety Quotient 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 RMR from total EI)[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.*[41] suggest that energy density may influence satiety responsiveness and that SQ may predict IE.

Association between Satiety Quotient 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]. In regard to 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.*[9] showed in their 5-year study that changes in SQ were negatively correlated with the change in waist circumference. With regard to the relationship between SQ and fat mass, Salama *et al.*[11] found a positive relationship between % fat mass and SQ_F. In their longitudinal study, McNeil *et al.*[9] 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.

Association between Satiety Quotient 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] has 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 *v.* a rest condition[43].

Satiety Quotient 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 with 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 behavioural 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.*[13] showing that SQ negatively correlated with the external locus for Hunger measured by the Three-Factor Eating Questionnaire. Moreover, Buckland *et al.*[58] found a weaker control over eating and weight loss programme adherence in people with a low satiety phenotype, as well as a lower weight loss compared with people with a high satiety phenotypes.

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 analyse the available evidence regarding the scientific and clinical use of the SQ. Fifty-two studies were included after our database search, thirty-three of them being cross-sectional/acute[6–8,11,13–15,18–42] and nineteen being longitudinal[9,10,12,43–59]. The large majority of the included studies enrolled adults participants with only four 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], sex[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 Satiety Quotient

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] EI, as well as macronutrient intake[9]. Studies effectively highlight higher food consumption with lower satiety responsiveness to a meal (lower SQ) in type 1 diabetes[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.*[58] in women with obesity. The SQ has been used as a clinical tool to categorise people depending on their level of satiety responsiveness to a standardised fixed meal; a low phenotype characterising people who report difficulties in appropriately recognising their appetite sensations before or after a meal[8]. These results are supplemented by those of Buckland *et al.*[58], which have shown that people with low satiety phenotype have a weaker control over eating and weight loss programme adherence compared with people with high satiety phenotype. 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 categorise 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 Three-Factor Eating Questionnaire); 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 EI 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.*[39] found increased SQ for Hunger, Prospective Food Consumption and Desire To Eat after acute moderate intensity exercise in adolescents with obesity. Kral *et al.*[41]and coworkers suggested a beneficial effect of a low energy density preload on satiety responsiveness in children. 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 was 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 forty-three out of the forty-eight adults studies included[6–14,18–20,22–37,40,43–54,56–59] used the equation initially developed by Green *et al.*[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

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used (e.g. 100 *v.* 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 standardised 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 *et al.* 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 with 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 response to weight loss, we also encourage the adoption of a more standardised 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 standardised 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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Supplementary material

For supplementary material referred to in this article, please visit https://doi.org/10.1017/S0007114520002457

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