The association between childhood adiposity and appetite assessed using the Child Eating Behaviour Questionnaire and Baby Eating Behaviour Questionnaire: A systematic review and meta-analysis.

Alice Kininmonth[1], MSc*; Andrea Smith, PhD*[2]; Susan Carnell[3], PhD; Silje Steinsbekk[4], PhD; Alison Fildes[1], PhD*; and Clare Llewellyn[2], PhD*

*Joint senior author, *Joint first author*

[1] School of Psychology, Faculty of Medicine and Health, University of Leeds, Leeds, United Kingdom.

[2] Obesity Group, Research Department of Behavioural Science and Health, University College London, London, United Kingdom.

[3] Department of Psychiatry and Behavioural Sciences, Johns Hopkins University School of Medicine, Baltimore, USA.

[4] Department of Psychology, Faculty of Social and Educational Sciences, Norwegian University of Science and Technology, Norway.

Running title: Appetite and adiposity in childhood

Key words: Appetite, Child, Adiposity, Meta-analysis

Address reprint requests and correspondence to:

Dr Alison Fildes

School of Psychology,

Faculty of Medicine & Health

University of Leeds

Leeds, LS2 9JT

United Kingdom.

E-mail: A.Fildes@leeds.ac.uk

Acknowledgements: We thank Shauna Farrell, Lewis Cox, Katelyn Sass and Kristiane Tommerup for supporting the screening process and quality checking. We would like to thank the following list of authors who kindly provided additional data, upon request. These analyses would not have been possible without your assistance and support. **Dr Karina Lora**; Department of Allied Health Sciences, University of Oklahoma, USA. **Dr Emma Haycraft;** School of Sport, Exercise and Health Sciences, University of Loughborough, UK**. Dr Corjan de Groot;** Leids Universitair Medisch Centrum, The Netherlands**. Dr Aino-Maija Eloranta** & **Professor Timo Lakka**; Institute of Biomedicine, School of Medicine, University of Eastern

Finland, Finland. **Dr Tom Power, Dr Karen Silva Garcia** & **Professor Sheryl O. Hughes**; Children's Nutrition Research Center, Baylor College of Medicine, USA. **Dr Matthew Cross**; Texas Women's University, USA. **Professor Robert Soussignan**; Centre des Sciences du Goût et de l'Alimentation (Dijon), Université de Reims Champagne-Ardenne, France. **Dr Charlotte Hardman**; Department of Psychological Sciences, University of Liverpool, UK. **Dr Rachel L. Vollmer**; Department of Family and Consumer Sciences, Bradley University, USA. **Dr Heidi Bergmeier;** School of Public Health and Preventive Medicine, Monash University**. Dr Abby Lynn Braden;** Department of Psychology, Bowling Green State University. **Dr Laura Webber;** Co-founder & COO, HealthLumen, UK. **Dr Sarah Domoff;** Department of Psychology, Central Michigan University, USA. **Dr Mary F.F. Chong & Dr Phaik L. Quah**; Singapore Institute for Clinical Science, Singapore. **Dr Jodie Stearns & Professor John Spence;** Faculty of Kinesiology, University of Alberta, Canada. **Dr Elaine McCarthy & Professor Mairead Kiely**; Irish Centre for Fetal and Neonatal Translational Research [INFANT], University College Cork, Ireland. **Dr Patricia P Silveria;** Department of Psychiatry, McGill University, Canada. **Arend Van Deutekom;** Department of Pediatrics, Amsterdam University Medical Center, The Netherlands. **Eline E. Vos & Prof Mai Chin A Paw**; Institute for Health and Care Research, Amsterdam UMC, Universitair Medische Centra, The Netherlands. **Dr Jennifer E. Emond;** Department of Biomedical Data Science, Dartmouth Geisel School of Medicine, USA. **Prof Poh Bee Koon & Dr Yitsiew Chin** & SEANUTS Malaysia Study Group; Faculty of Health Sciences, Universiti Kebangsaan Malaysia, Malaysia.

Conflicts of interest: Dr. Llewellyn reports grants from Economic and Social Research Council, grants from Best Beginnings (UK charity), during the conduct of the study; personal fees from Yellow Kite, personal fees from The Experiment, personal fees from Diamond Inc, outside the submitted work.

Abbreviations

CEBQ, Child Eating Behaviour Questionnaire

BEBQ, Baby Eating Behaviour Questionnaire

FR, Food Responsiveness

EF, Enjoyment of Food

EOE, Emotional Overeating

DD, Desire to Drink

SR, Satiety Responsiveness

SE, Slowness in Eating

EUE, Emotional Undereating

FF, Food Fussiness

GA, General Appetite

BMI, Body mass index

BST, Behavioural Susceptibility Theory

DEBQ, Dutch Eating Behaviour Questionnaire

TFEQ, Three Factor Eating Questionnaire

AEBQ, Adult Eating Behaviour Questionnaire

Abstract

This systematic review and meta-analysis aimed to quantify associations between Child - (CEBQ) and Baby (BEBQ) - Eating Behaviour Questionnaire appetitive traits (food approach: Food Responsiveness [FR], Enjoyment of Food [EF], Emotional Overeating [EOE], Desire to Drink [DD]); food avoidant: Satiety Responsiveness [SR], Slowness in Eating [SE], Emotional Undereating [EUE], Food Fussiness [FF]) and measures of child adiposity. Searches of six databases up to February 2019 identified 72 studies (CEBQ, n=67; BEBQ, n=5), 27 met meta-analysis criteria. For cross-sectional studies reporting unadjusted correlations with BMIz (n=19), all traits were associated with BMIz in expected directions (positive: FR, EF, EOE, DD; negative: SR, SE, EUE, FF). Pooled estimates ranged from r=0.22 (FR) to r=-0.21 (SR). For cross-sectional studies reporting regression coefficients (n=10), three traits (FR, EF, EOE) associated positively, and three traits (SR, SE, EUE) negatively, with BMIz (β=-0.31 [SR] to β=0.22 [FR]). Eleven studies reported prospective relationships from appetite to adiposity measures for six scales (positive: FR, EF, EOE, DD; negative: SR, SE). Five studies reported relationships from adiposity measures to appetite for five traits (positive: FR, EF, EOE; negative: SR). All BEBQ-traits were consistently cross-sectionally associated with adiposity measures. Overall, CEBQ/BEBQ-assessed appetitive traits show consistent cross-sectional relationships with measures of child adiposity.

INTRODUCTION

Behavioural susceptibility theory (BST) was developed to explain how the food environment interacts with genetic susceptibility to influence weight[1,2]. BST proposes that differences in appetite determine why some people over- or under-eat, and others do not, in response to environmental opportunity[3]. Those who inherit genes promoting an avid appetite are vulnerable to overeating and developing obesity, while those who are genetically predisposed to have a smaller appetite and low interest in food are protected, or even at risk of underweight. By identifying these traits and their early precursors we may be able to prevent unhealthy weight trajectories. Twin studies demonstrate that, like body weight[4,5], appetitive traits have a strong genetic basis[6–8], and studies using measured genetic obesity risk indicate that appetite mediates the association between obesity-associated genetic variants and adiposity[9,10].

The Child Eating Behaviour Questionnaire (CEBQ),[11] was developed to test BST nearly twenty years ago. It has since been translated into fourteen languages and has become one of the most widely used psychometric measures of appetitive traits, with the development and validation papers receiving over 1500 citations to date [11,12]. The CEBQ has been used to investigate associations of child eating behaviour with environmental factors (e.g. parent feeding behaviours) as well as genetic factors [13,14]. The CEBQ is a comprehensive 35-item parent-report measure assessing eight appetitive traits. Most of the traits captured by the CEBQ were conceptualised on the basis of existing literature examining dimensions of eating behaviour thought to relate to obesity risk [15]. The CEBQ comprises four ‘food approach’ traits which characterise a larger, more avid appetite and a greater interest in food. Higher scores on these scales indicate a heartier appetite. Four ‘food avoidant’ traits characterize a smaller appetite and lower interest in food. Higher scores on these scales indicate a smaller appetite. Scales from the CEBQ have been validated against behavioural tests of appetite in pre-schoolers[12].The Baby Eating Behaviour Questionnaire (BEBQ) is an infant version of the CEBQ that assesses four of the appetitive traits and has been developed to capture variation in appetitive tendencies during the first six months of life[16].

The first study to explore relationships between CEBQ measured appetite traits and child adiposity demonstrated that the ‘food approach’ trait, food responsiveness was positively associated, and the ‘food avoidant’ trait satiety responsiveness was negatively associated, with both child BMI and waist circumference [17]. Relationships were linear across the weight spectrum but associations were stronger for waist circumference than for BMI, which could reflect the fact that waist circumference is a more direct measure of adiposity. The main clinical parameters for characterising paediatric body composition draw on weight, height, BMI and waist circumference measures [18]. BMI is not an ideal measure because it reflects relative leg length, body frame size, and fat-free mass in addition to levels of adipose tissue. However, measures such as BMI percentile or BMI z-score remain the most pragmatic and therefore most commonly applied approach for studying variation in paediatric body composition in relation to health outcomes, both at the individual and population level.

Numerous studies have now examined associations between all of the appetitive traits assessed with the BEBQ and CEBQ, and measures of adiposity in infancy and childhood[19–21]. The present inquiry is the first to systematically review and meta-analyse these studies, with the goal of strengthening the evidence base for the relationship between appetite and child adiposity. Rigorous investigation into the relationships between different dimensions of appetite and weight across childhood is needed to evaluate BST – one of the original purposes of the CEBQ and BEBQ. A stronger evidence base for the relationship between appetite and weight in childhood would inform prevention and treatment of overweight and underweight/weight-related disorders, for example, by suggesting behavioural targets for environmental or clinical interventions. Confirmation of the relationship between CEBQ- and BEBQ-assessed appetitive traits and adiposity would support use of these questionnaires to investigate environmental as well as genetic influences on child eating behaviour (e.g. parent feeding behaviours), within a behaviour genetics framework [13]. While other measures have been applied to study relationships between appetite and weight (e.g. Dutch Eating Behaviour Questionnaire [DEBQ])[22], the CEBQ and BEBQ were specifically developed for pediatric use and to assess a broader range of traits implicated in development of both overweight and underweight, and are thus the focus of this review.

The primary objectives of this study were to: (i) conduct a systematic review to assess how CEBQ- and BEBQ-assessed appetitive traits relate to adiposity and prospective weight gain from birth to 18 years; and (ii) establish the size of the associations using meta-analysis.

METHODS

The systematic review and meta-analysis followed the PRISMA reporting guidelines and was registered on PROSPERO (Registration Number: CRD42017081218.).

Search strategy and selection criteria

A systematic search of the following six electronic databases was conducted: Medline, EBSCO CINAHL, Cochrane Library, EMBASE, Web of Science and PsycInfo until February 2019. Search terms were developed using combinations of relevant keywords and MESH terms and were searched for within relevant titles and abstracts. The search strategy is outlined in **Table S1.** The reference list for relevant papers was also hand searched to capture any additional studies that were not identified in the search.

Studies were included if they were observational and reported at least one CEBQ- or BEBQ-measured trait. The CEBQ includes eight scales. Four assess ‘food approach’ traits: Enjoyment of Food (4 items; EF; e.g. ‘My child loves food’), Food Responsiveness (5 items; FR; e.g. ‘Given the choice, my child would eat most of the time’), Emotional Overeating (4 items; EOE; e.g. ‘My child eats more when worried’), Desire to Drink (3 items; DD; e.g. ‘My child is always asking for a drink’). Four assess ‘food avoidant’ traits: Food Fussiness (6 items; FF; e.g. ‘My child refuses new foods at first’), Emotional Undereating (4 items; EUE; e.g. ‘My child eats less when he/she is tired’), Slowness in Eating (4 items; SE; e.g. ‘My child eats slowly’), Satiety Responsiveness (5 items; SR; e.g. ‘My child gets full up easily’). The BEBQ assesses FR (5 items; e.g., ‘My baby was always demanding a feed'), EF (4 items; e.g. 'My baby loved milk'), SE (4 items; e.g. 'My baby fed slowly'), SR (5 items; 'My baby got full up easily') and a single item which correlates with all four scales, 'General appetite' (GA; e.g. 'My baby has a big appetite'). Each item is scored using a 5-point Likert scale (1=never, 2=seldom, 3=sometimes, 4=often, 5=always). Scale scores are means of all scale items. Higher scores indicate more frequent demonstrations of behaviours characterizing the trait. Further details of questionnaire development are published elsewhere[11,16].

In line with the WHO's definition of childhood, the population of interest was children aged <18 years [23], Meta-analysis was planned for all articles with sufficient data on the relationship between any scale (CEBQ or BEBQ) and any measure of adiposity (e.g. BMI z-score, BMI percentile, waist circumference or any measure of body composition). Papers not eligible for quantitative analysis were reviewed narratively, including studies providing quantitative estimates of differences in mean CEBQ or BEBQ scale scores across weight categories (e.g. underweight, healthy weight, overweight and obesity). Studies were excluded from the review if CEBQ/BEBQ scales had been modified from the original format (e.g. reorganizing scales into new dimensions such as 'Appetite Restraint' and 'Appetite Disinhibition'), or they were not published in English and no translation was available (n = 8). Eighteen studies incorporated modifications to one or more scales. As multiple studies (n=6) combined SR and SE into one composite scale these observations were retained in the narrative review. Study eligibility was assessed independently by two reviewers (AS and AK), and disagreements discussed until consensus was reached. See **Tables 1-5** for a summary of the study characteristics.

Data extraction and quality assessment of included studies

Descriptive data on the study characteristics, appetitive traits measured, adiposity measure used, and effect estimates of the relationship between appetitive traits and adiposity were extracted by two reviewers (AK and AS). Degree of adjustment for the reported effect estimates varied across studies. Both crude and the maximally adjusted values were extracted (i.e. the reported effect estimates within the individual study adjusted for the most covariates). For duplicate cohorts, the most complete study was taken forward (based on the greatest number of appetitive scales reported or highest n). Where necessary, authors were contacted to request additional information (n= 45, e.g. authors provided specific correlation or regression coefficients for individual subscales when not specifically reported in the main manuscript).

Risk of bias was assessed and cross-checked by two reviewers (AK and AS). An overall risk of bias score was obtained using the semi-quantitative Newcastle Ottawa Scale (NOS). The NOS assesses three main areas of study quality, namely 1) the selection of the cohort, 2) the comparability of study analysis, and 3) the ascertainment of the outcome. The NOS tool was adapted as necessary to assess the quality of the included study designs. A NOS score $\geq$7/10 was considered indicative of high study quality (see **Table S2**[24]).

Data synthesis for meta-analysis

Studies were classified based on whether effect estimates of associations between appetitive traits and adiposity measures were reported as correlation coefficients (r) and/or standardized regression coefficients (β). These measures were selected because they were most commonly reported. In order to utilise adiposity measures, a minimum of three studies was needed to pool effect estimates[25]. Therefore, only BMI z-scores (BMIz) were used in the meta-analytical models as insufficient data existed for other outcomes (e.g. body composition (n=3), weight-for-age (n=1))[26].

There were insufficient data to meta-analyse prospective studies, due to high heterogeneity in outcome measures and follow-up time (see **Table 3**), or studies using the BEBQ, due to variation in reported weight outcomes (see **Table 5**).

Statistical analysis for meta-analysis

Random effects meta-analysis using data from eligible studies was performed to approximate an overall pooled weighted mean effect estimate[25]. The random effects model was used to account for anticipated inter-study variance.

Meta-analytic models for unadjusted correlation coefficient effect estimates with BMIz were conducted. In addition, analyses stratified by level of adjustment were undertaken to assess whether the pooled effect size was sensitive to adjustment strategy.

Assessment of between-study heterogeneity was judged by the p-value for heterogeneity and calculation of the I^2 values. Moderate between-study heterogeneity was considered >50% for I^2 with levels of 75% deemed indicative of high inconsistency in approximation of the summarised effect size[27]. Subgroup analyses explored potential heterogeneity by age of participant or year of publication. Publication bias was assessed by funnel plot and Egger's test; a p value of <.01 was considered sufficient evidence of no publication bias[28]. Statistical analyses were performed using Stata v15 with a p-value of <.05 considered significant.

RESULTS

Literature search

A total of 2416 papers were retrieved; 1338 remained after duplicate removal. 72 independent studies were eligible for inclusion in the final review (See **Figure 1)**. 67 studies explored relationships between CEBQ scales and adiposity (n=54 cross-sectional, n=12 prospective) and five relationships between BEBQ scales and adiposity (n=1 cross-sectional, n=4 prospective). Five CEBQ prospective studies also examined cross-sectional relationships between appetitive traits and adiposity; these results are discussed separately.

Characteristics of included studies

CEBQ studies (n=67)

Study descriptives are in **Tables 1-3**. Sample sizes ranged from n=37[29] to n=10,364[6]. All samples were mixed sex, with ages from 1 month[30] to 13 years[31,32]. Most studies used the

English language version of the CEBQ (n=40). Seventeen studies provided data on all 8 CEBQ scales, while the remaining studies reported on a reduced subset of the scales (n=50). Various measures of adiposity were reported including BMI z-scores (n=45), BMI percentile (n=5), BMI (n=3), weight (n=1), body fat percentage (n=1), and weight-for-age z-scores (n=2), and two studies used multiple measures of adiposity (body fat percentage, muscle mass, and BMI z-score) [20,33]. Study quality was inconsistent; 23 were rated as poor on the NOS scale, and among these, two included separate ratings for sub cohort data which were deemed of higher quality[34,35] **(Table S2)**

BEBQ studies (n=5)

Five studies reported BEBQ data. Samples varied from n=31[36] to n=4804[37]. The BEBQ is designed for use with infants, explaining the younger age range observed (0 - 24 months of age). All studies used the English version of the BEBQ, with most studies reported for all four BEBQ scales (n=4). Four studies elicited parent-reports of current appetitive traits, whilst one study used a combination of current and retrospective reports for the first 3 months of life[37]. With respect to outcome measures, three studies reported BMI and two BMI z-scores. Four studies were rated high quality based on the NOS criteria (see **Table S2**), with only one study rated lower quality[36].

Meta-analyses of cross-sectional CEBQ studies (n=27)

In a random effects meta-analysis model, mean bivariate correlation coefficients for associations between the eight CEBQ scales and BMIz were combined (n=19 maximum). All estimates were significant and in expected directions; food approach scales (FR, EF, EOE, DD) were correlated positively, and food avoidant scales (SR, SE, FF, EUE) were negatively, with BMIz. All associations were small in size[38]. The largest associations were observed between FR and BMIz r=0.22 (95% CI: 0.16, 0.29; I^2=88.0%; n=9463), and between SR and BMIz r= -0.21 (95% CI: -0.24, -0.17; I^2=56.7%; n=9854). Detailed summaries of the pooled effect estimates and their 95% CIs, for each CEBQ scale, ae shown in **Table 6** and **Figure 2**.

In an overall random effects model pooling data from all eligible studies presenting regression coefficients between CEBQ scales and BMIz (n=13), the maximally adjusted standardized effect estimates (β) were prioritised. If unavailable, the crude estimates (i.e. equivalent to a Pearson's correlation coefficient) were taken forward. Six out of eight scales were significantly associated with BMIz in the adjusted estimates in expected directions. Strongest associations were observed for SR β=-0.31 (95% CI: -0.40, -0.23; I^2=94.0%; n=9800) and FR β=0.22 (95% CI: 0.11, 0.34; I^2=93.2%; n=5707) with BMIz. FF and DD were not significantly associated with BMIz. Full results for the overall pooled models, as well as the adjusted only and crude only meta-analyses are shown in **Table 7** and **Figure 3.**

Narrative Review of CEBQ studies

Cross-sectional CEBQ studies

In the 54 studies reporting on cross-sectional associations between the CEBQ and measures of adiposity, five appetitive traits were consistently associated with child adiposity in expected directions. Positive associations were reported for FR (24/29 studies), EF (21/28) and EOE (12/22), and negative associations for SR (22/25), SE (12/19) and SR/SE combined (2/2). Null associations were reported for EUE (10/17), FF (12/19) and DD (15/22). Descriptive summaries of these relationships are presented in **Table S3.**

Nineteen cross-sectional studies reported data on differences in mean CEBQ scale scores by weight categories. There were substantial variability in number of categories (ranging from 2 to 5), and the adiposity thresholds and reference data used to define them (see Table 2). Just over half (11/19) of studies tested for trends of linearity in scale scores across adiposity categories. Positive linear trends were observed for FR (10/10), EF (9/10), EOE (8/8) and DD (6/7), and negative linear trends for SR (7/7), SE (4/4), FF (4/7), and SR/SE (3/3). No association was observed for EUE (5/6). Findings are summarised in see **Table S4.**

Prospective CEBQ studies

Only 11 studies explored prospective associations between the CEBQ and adiposity, all adjusting for baseline adiposity[19,20,33,34,39–45]. Most studies used BMIz (n=9), but BMI percentile (n=1), and multiple other indicators (n=1) were also reported. Six appetitive traits were consistently associated with child adiposity in expected directions, with positive associations for FR (6/8 studies), EF (5/7), EOE (5/5) and DD (3/3), and negative associations for SR (5/7) and SE (3/5). Null associations were reported for FF (4/5) and EUE (2/2). Studies reporting the opposite direction of influence (n=5), showed consistent positive associations between adiposity and later FR (4/5), EF (2/3) and EOE (2/3), and negative associations for SR (4/5). Of these, five studies also reported on the reverse relationships, from baseline CEBQ scores to later adiposity[20,30,46–48]. Only one study explored prospective relationships from adiposity to later appetitive traits, but did not examine bidirectionality[49]. Results are summarised in **Table S3**.

BEBQ studies (n=5)

Four of five identified studies explored prospective relationships between BEBQ scales and adiposity (Patel et al., 2017). Only two studies reported cross-sectional associations (Patel 2018; Quah 2015), so meta-analysis for the BEBQ estimates was not undertaken. Positive associations with adiposity were reported for FR (3/5), EF (4/5) and GA (3/3), and negative associations for SR (2/4) and SE (3/3). A descriptive summary of the direction of the observed relationships in these papers is presented in **Table S3.**

DISCUSSION

The CEBQ and BEBQ were designed to capture individual differences in appetitive traits hypothesised to contribute to the development of overweight and underweight. These questionnaires have been used extensively since their inception, but this is the first systematic examination of relationships between appetitive traits, and measures of adiposity across childhood.

Pooled estimates based on 27 eligible studies for inclusion in the meta-analysis demonstrated that six CEBQ scales were associated with BMI z-scores in hypothesised directions. Three food approach scales (FR, EF, EOE) were consistently positively associated with adiposity, with the largest association observed for FR (r=.22, β=.21). Three food avoidant scales (SR, SE, EUE) were consistently negatively associated with adiposity, with the largest association observed for SR (r=-.21, β=-.33). In contrast, associations of DD and FF with BMI-z scores were mixed, with only studies reporting correlations yielding significant pooled estimates. Findings were broadly consistent across relationships evaluated in the narrative review and for the fewer BEBQ studies. For studies examining linearity of associations across weight categories, results were graded in the expected direction for all CEBQ scales except EUE, which was unrelated to weight status. The small number of studies reporting prospective relationships between appetite and adiposity suggested bidirectional associations.

Together these findings support the central hypothesis of behavioural susceptibility theory – that appetitive traits are a key behavioural mechanism that help to explain an individual's susceptibility to gain excess weight (or not) in response to the obesogenic environment. However, findings also indicate that adiposity itself may lead to changes in appetite over time, such that children of higher adiposity develop increasingly avid appetites. Although future prospective studies are needed to reveal the direction of influence, this impact of weight on appetite is potentially problematic for weight loss interventions targeting eating behaviour and highlights the importance of obesity prevention and management of appetite from infancy.

The CEBQ was originally developed as a multi-dimensional measure of the appetitive traits implicated in the development of body weight in children. Most traits captured by the CEBQ were conceptualised based on existing literature examining dimensions of eating behaviour[15]. For example, FR and SR were developed from experimental laboratory studies which identified clusters of behaviours (e.g. eating without hunger, palatability responsiveness) linked to increased obesity risk[15,50,51]. Early work revealed differences in these traits, with greater responsiveness to food cues, and lower responsiveness to internal cues of satiety, observed in individuals with obesity, compared to those with a healthy weight [15,51–53]. However, two traits, EUE and DD, were added following open-ended parent interviews and these scales showed less clear adiposity relationships, possibly due to ambiguity in what they assess. For example, DD assesses general wanting for drinks, without specifying beverage types. Distinguishing between the preference for water versus a caloric beverage (e.g. sugar-sweetened drinks or milk) may be necessary to clarify associations with energy intake and therefore weight[54]. There were also inconsistencies in the EUE-adiposity relationship. EUE was commonly excluded from studies, resulting in a smaller analysis sample, so the inconsistency may have resulted from lower statistical power. Additionally, EUE scores may partly capture occurrence of a ‘state’, i.e. how often a child gets upset around mealtimes. For example, parents who pressure their children to eat may trigger a state of food anxiety, resulting in the expression of EUE behaviours regardless of their appetitive trait[55,56].

The unclear relationship between FF and adiposity revealed is unsurprising. Food fussiness characterises two aspects: eating a limited range of foods, and refusal of unfamiliar foods (‘food neophobia’). Both behaviours contribute to lower dietary variety, which is associated with poorer diet quality. Parents worry about fussy eating because it could lead to a child eating too little, or consuming insufficient variety for optimal development[57]. FF *has* been associated with under-eating and failure to thrive in children[58] but also with overconsumption of energy dense foods[59–61]. FF may not confer risk of underweight if adequate quantities of food are consumed, even if diet quality remains poor.

The small number of studies (n=11) reporting prospective relationships between appetite and adiposity, limits our ability to draw conclusions regarding the likely direction of influence between appetitive traits and weight development. Even fewer studies (n=5) examined bidirectional relationships, but all were supportive of bidirectional associations. While tentative evidence supports the hypothesis that an avid appetite predisposes to weight gain, it is possible the influence of appetite on weight development is greater during infancy, with adiposity level becoming more important in shaping appetite later in childhood.

Limitations

Heterogeneity in reporting and in adiposity measures (e.g. BMI z-score versus BMI percentiles) prevented the inclusion of more studies in the meta-analytic model, and meta-analysis of prospective effect estimates. Additionally, we were unable to include several studies that modified the CEBQ from its original, validated form (n=18) – e.g. studies that dropped items from scales, moved items into other scales, split scales, or created new scores for scales.

While the focus of this review was all measures of child adiposity, the majority of studies utilised BMI z-scores as the primary outcome and thus it was only possible to include BMI z-score in the meta-analytic model. There are a number of limitations to using BMI as an indicator of adiposity. BMI only acts a surrogate measure and cannot differentiate between weight attributable to fat mass or lean mass and thus misclassification of weight status can occur at an individual level, especially during childhood when maturation occurs at differing rates [62–64]. Furthermore, studies have highlighted the specific measurement used, e.g. BMI vs BMI z-scores vs BMI percentiles, may provide different results when examining changes in adiposity over time[63,65]. While BMI z-score is a valuable screening tool, it is not recommended as an appropriate diagnostic method for clinically assessing adiposity and should be used in conjunction with other measures of body composition in clinical practice[63]. However, BMI measures continue to be commonly employed in population research because they offer a practical and affordable method for assessment at scale, thus representing the best available indicator for this investigation.

Studies examining appetite in relation to weight status primarily focused on differences between children with healthy weight and overweight, rather than relationships between appetitive traits across the weight spectrum. Research in children with underweight is necessary to uncover how appetitive traits influence under-eating and the development of disordered eating behaviours, for example, to identify the age at which children might start to express active food restriction or excess consumption.

Only CEBQ and BEBQ-measured appetitive traits were included in this review. Other existing validated psychometric measures such as the DEBQ and Three Factor Eating Behaviour Questionnaire (TFEQ)[53] were not specifically developed for children, and capture a narrower range of appetitive traits. Confining our analysis to the CEBQ and BEBQ facilitates future comparisons across the life course via the Adult Eating Behaviour Questionnaire (AEBQ), which matches the appetitive trait factor structure of the CEBQ[66].

There were only a small number of bidirectional studies and those identified varied widely in period of follow-up, age-range, and frequency of assessment. Further analysis of prospective data from birth are needed to understand dynamic changes in direction and strength of the appetite-adiposity relationship across childhood. Future studies should also consider methods for disentangling between-person from within-person effects and discounting effects of all time-invariant confounders (e.g. sex or ethnicity), thereby separating the within-person level from confounding group-level association and moving closer to true causation of the appetite-adiposity relationship[67]. Research examining the impact on child adiposity of interventions that effectively modify appetitive traits could also inform on causality.

Implications

Notwithstanding these limitations, our findings suggest interventions targeting appetitive traits may provide a novel opportunity in obesity prevention and treatment, with potential implications for clinical practice and population health. Tailoring interventions to individuals' problematic appetitive traits may encourage behaviour change, influencing efficacy of lifestyle interventions (e.g. reducing emotional eating as a stress coping mechanism)[68]. E-health interventions show small positive effects of tailoring based on factors such as dietary intake, on weight loss success[69,70]. Preliminary research tailoring treatment targeting food-cue reactivity and satiety responsiveness in adults with binge eating demonstrated clear reductions in episodes of overeating, and BMI over a 4 month treatment period, with results maintained at 3-month follow-up[71]. Future work aims to apply this approach to children[72]. Establishing optimal BEBQ or CEBQ scale cut-off values for prediction of the development of overweight would support this work by helping to identify children at risk, informing algorithms to support clinical decision-making, and highlighting the most effective appetitive traits to target to support healthy weight management. At a population health level, even if tailoring is not possible, incorporating individual variation in appetitive traits with known adiposity impacts could improve models aiming to assess or predict impacts of environmental interventions to prevent child obesity[73,74].

CONCLUSION

The studies reviewed provide preliminary support for the hypothesis that a more avid appetite – higher scores on CEBQ and BEBQ food approach traits and lower scores on food avoidant traits – predisposes to excess weight gain and increased risk of overweight during childhood. However, evidence remains weak; most studies were cross-sectional, precluding conclusions about causal directions, and there were too few bidirectional prospective studies to detect effects reliably. More prospective research from birth is needed to establish causality, and to investigate bidirectional relationships between appetite and adiposity which may change in direction and strength throughout development. Nevertheless, this is the most comprehensive synthesis of published evidence on the relationship between appetitive traits and adiposity in childhood to date. Results provide a foundation for future prospective research to understand how appetitive traits mediate the influence of the obesogenic environment on body weight trajectories.

REFERENCES

1. Carnell S, Haworth CMA, Plomin R, Wardle J. Genetic influence on appetite in children. *Int J Obes (Lond)*. 2008;32(10):1468-1473. doi:10.1038/ijo.2008.127
2. Carnell S, Wardle J. Appetite and adiposity in children: evidence for a behavioral susceptibility theory of obesity. *Am J Clin Nutr*. 2008;88(1):22-29.
3. Llewellyn C, Wardle J. Behavioral susceptibility to obesity: Gene–environment interplay in the development of weight. *Physiol Behav*. 2015;152:494-501. doi:https://doi.org/10.1016/j.physbeh.2015.07.006
4. Elks CE, den Hoed M, Zhao JH, et al. Variability in the Heritability of Body Mass Index: A Systematic Review and Meta-Regression. *Front Endocrinol (Lausanne)*. 2012;3(FEB):29. doi:10.3389/fendo.2012.00029
5. Silventoinen K, Jelenkovic A, Sund R, et al. Genetic and environmental effects on body mass index from infancy to the onset of adulthood: an individual-based pooled analysis of 45 twin cohorts participating in the COllaborative project of Development of Anthropometrical measures in Twins (CODATwins) study. *Am J Clin Nutr*. 2016;104(2):371-379. doi:10.3945/ajcn.116.130252
6. Carnell S, Wardle J. Appetite and adiposity in children: evidence for a behavioral susceptibility theory of obesity. *Am J Clin Nutr*. 2008;88(1):22-29. http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=105791809&site=ehost-live.
7. Llewellyn CH, van Jaarsveld CHM, Johnson L, Carnell S, Wardle J. Nature and nurture in infant appetite: analysis of the Gemini twin birth cohort. *Am J Clin Nutr*. 2010;91(5):1172-1179. doi:10.3945/ajcn.2009.28868
8. Llewellyn CH, van Jaarsveld CHM, Plomin R, Fisher A, Wardle J. Inherited behavioral susceptibility to adiposity in infancy: a multivariate genetic analysis of appetite and weight in the Gemini birth cohort. *Am J Clin Nutr*. 2012;95(3):633-639. http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=108164473&site=ehost-live.

9. Jacob R, Drapeau V, Tremblay A, Provencher V, Bouchard C, Pérusse L. The role of eating behavior traits in mediating genetic susceptibility to obesity. *Am J Clin Nutr*. 2018;108:445-452. doi:10.1093/ajcn/nqy130

10. Llewellyn CH, Trzaskowski M, van Jaarsveld CH, Plomin R, Wardle J. Satiety mechanisms in genetic risk of obesity. *JAMA Pediatr*. 2014;168(4):338-344. doi:https://dx.doi.org/10.1001/jamapediatrics.2013.4944

11. Wardle J, Guthrie CA, Sanderson S, Rapoport L. Development of the Children's Eating Behaviour Questionnaire. *J Child Psychol Psychiatry Allied Discip*. 2001;42(7):963-970. doi:10.1017/S0021963001007727

12. Carnell S, Wardle J. Measuring behavioural susceptibility to obesity: Validation of the child eating behaviour questionnaire. *Appetite*. 2007;48(1):104-113. doi:10.1016/j.appet.2006.07.075

13. Kral TVE, Faith MS. Child eating patterns and weight regulation: a developmental behaviour genetics framework. *Acta Paediatr*. 2007;96(SUPPL. 454):29-34. doi:10.1111/j.1651-2227.2007.00167.x

14. Faith MS, Carnell S, Kral TVE. Genetics of food intake self-regulation in childhood: Literature review and research opportunities. *Hum Hered*. 2013;75(2-4):80-89. doi:10.1159/000353879

15. Schachter S. Obesity and eating. *Science (80-)*. 1968;161(3843):751-756. doi:10.1126/science.161.3843.751

16. Llewellyn CH, van Jaarsveld CH, Johnson L, Carnell S, Wardle J. Development and factor structure of the Baby Eating Behaviour Questionnaire in the Gemini birth cohort. *Appetite*. 2011;57(2):388-396. doi:https://dx.doi.org/10.1016/j.appet.2011.05.324

17. Carnell S, Wardle J. Appetite and adiposity in children: evidence for a behavioral susceptibility theory of obesity. *Am J Clin Nutr*. 2008;88(1):22-29. http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=105791809&site=ehost-live.

18. Horan M, Gibney E, Molloy E, McAuliffe F. Methodologies to assess paediatric adiposity.

Ir J Med Sci. 2015;184(1):53-68. doi:10.1007/s11845-014-1124-1

19. Quah PL, Chan YH, Aris IM, et al. Prospective associations of appetitive traits at 3 and 12 months of age with body mass index and weight gain in the first 2 years of life. *BMC Pediatr*. 2015;15:153. doi:https://dx.doi.org/10.1186/s12887-015-0467-8
20. Derks IPM, Sijbrands EJG, Wake M, et al. Eating behavior and body composition across childhood: a prospective cohort study. *Int J Behav Nutr Phys Act*. 2018;15(1):1-9. doi:10.1186/s12966-018-0725-x
21. van Jaarsveld CH, Llewellyn CH, Johnson L, Wardle J. Prospective associations between appetitive traits and weight gain in infancy. *Am J Clin Nutr*. 2011;94(6):1562-1567. http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=108207259&site=ehost-live.
22. van Strien T, Frijters JER, Bergers GPA, Defares PB. The Dutch Eating Behavior Questionnaire (DEBQ) for assessment of restrained, emotional, and external eating behavior. *Int J Eat Disord*. 1986;5(2):295-315. doi:10.1002/1098-108X(198602)5:2<295::AID-EAT2260050209>3.0.CO;2-T
23. World Health Organisation. *WHO Definition of Key Terms*.; 2013. https://www.who.int/hiv/pub/guidelines/arv2013/intro/keyterms/en/. Accessed July 10, 2020.
24. Wells G, Shea B, Robertson J, et al. *The Newcastle-Ottawa Scale (NOS) for Assessing the Quality of Nonrandomized Studies in Meta-Analysis*.
25. DerSimonian R, Laird N. Meta-analysis in clinical trials. *Control Clin Trials*. 1986;7(3):177-188. doi:10.1016/0197-2456(86)90046-2
26. Valentine JC, Pigott TD, Rothstein HR. How Many Studies Do You Need? *J Educ Behav Stat*. 2010;35(2):215-247. doi:10.3102/1076998609346961
27. Higgins JPT, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. *BMJ*. 2003;327(7414):557-560. doi:10.1136/bmj.327.7414.557
28. Egger M, Smith GD, Schneider M, Minder C. Bias in meta-analysis detected by a simple , graphical test measures of funnel plot asymmetry. *Bmj*. 1997;315(7109):629-634.

doi:10.1136/bmj.315.7109.629

29. Mallan KM, Nambiar S, Magarey AM, Daniels LA. Satiety responsiveness in toddlerhood predicts energy intake and weight status at four years of age. *Appetite*. 2014;74:79-85. doi:https://doi.org/10.1016/j.appet.2013.12.001

30. van Deutekom AW, Chinapaw MJ, Vrijkotte TG, Gemke RJ. The association of birth weight and postnatal growth with energy intake and eating behavior at 5 years of age-A birth cohort study. *Int J Behav Nutr Phys Act Vol 13 2016, ArtID 15*. 2016;13. doi:http://dx.doi.org/10.1186/s12966-016-0335-4

31. Loh DA, Moy FM, Zaharan NL, Mohamed Z. Eating behaviour among multi-ethnic adolescents in a middle-income country as measured by the self-reported Children's Eating Behaviour Questionnaire. *PLoS ONE [Electronic Resour*. 2013;8(12):e82885. doi:https://dx.doi.org/10.1371/journal.pone.0082885

32. Viana V, Sinde S, Saxton JC. Children's Eating Behaviour Questionnaire: associations with BMI in Portuguese children. *Br J Nutr*. 2008;100(2):445-450. http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=105669370&site=ehost-live.

33. Steinsbekk, Llewellyn CH, Fildes A, Wichstrøm L. Body composition impacts appetite regulation in middle childhood. A prospective study of Norwegian community children. 2017;14(1):70.

34. Bergmeier H, Skouteris H, Horwood S, Hooley M, Richardson B. Child temperament and maternal predictors of preschool children's eating and body mass index. A prospective study. *Appetite*. 2014;74:125-132. doi:https://dx.doi.org/10.1016/j.appet.2013.12.006

35. Mallan KM, Liu WH, Mehta RJ, Daniels LA, Magarey A, Battistutta D. Maternal report of young children's eating styles. Validation of the Children's Eating Behaviour Questionnaire in three ethnically diverse Australian samples. *Appetite*. 2013;64:48-55. doi:https://dx.doi.org/10.1016/j.appet.2013.01.003

36. Shepard DN, Chandler-Laney PC. Prospective associations of eating behaviors with weight gain in infants. *Obesity*. 2015;23(9):1881-1885.

doi:https://dx.doi.org/10.1002/oby.21168

37. van Jaarsveld CH, Llewellyn CH, Johnson L, Wardle J. Prospective associations between appetitive traits and weight gain in infancy. *Am J Clin Nutr*. 2011;94(6):1562-1567. http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=108207259&site=ehost-live.

38. Chen H, Cohen P, Chen S. How big is a big odds ratio? Interpreting the magnitudes of odds ratios in epidemiological studies. *Commun Stat Simul Comput*. 2010;39(4):860-864. doi:10.1080/03610911003650383

39. Parkinson KN, Drewett RF, Le Couteur AS, Adamson AJ. Do maternal ratings of appetite in infants predict later Child Eating Behaviour Questionnaire scores and body mass index? *Appetite*. 2010;54(1):186-190. doi:10.1016/j.appet.2009.10.007

40. Mallan KM, Fildes A, Magarey AM, Daniels LA. The Relationship between Number of Fruits, Vegetables, and Noncore Foods Tried at Age 14 Months and Food Preferences, Dietary Intake Patterns, Fussy Eating Behavior, and Weight Status at Age 3.7 Years. *J Acad Nutr Diet*. 2016;116(4):630-637. doi:10.1016/j.jand.2015.06.006

41. McPhie S, Skouteris H, Fuller-Tyszkiewicz M, et al. Maternal predictors of preschool child-eating behaviours, food intake and body mass index: A prospective study. *Early Child Dev Care*. 2012;182(8):999-1014. doi:http://dx.doi.org/10.1080/03004430.2012.678595

42. Steinsbekk, Wichstrøm L, Wichstrom L. Predictors of Change in BMI From the Age of 4 to 8. *J Pediatr Psychol*. 2015;40(10):1056-1064.

43. Bjørklund, O. Belsky, J., Wichstrøm, Lars. & Steinsbekk S. Predictors of eating behavior in middle childhood: A hybrid fixed effects model. *Dev Psychol*. 2018;54(6):1099-1110.

44. Mallan K, Nambiar S, Magarey A, Daniels L. Satiety responsiveness in toddlerhood predicts energy intake and weight status at four years of age. *Appetite*. 2014;74:79-85. doi:10.1016/j.appet.2013.12.001

45. Escobar RS, O'Donnell KA, Colalillo S, et al. Better quality of mother-child interaction at 4 years of age decreases emotional overeating in IUGR girls. *Appetite*. 2014;81:337-342.

doi:https://dx.doi.org/10.1016/j.appet.2014.06.107

46. Koch A, Pollatos O. Interoceptive sensitivty, body weight and eating behavior in children: a prospective study. *Front Psychol*. 2014;5. doi:10.3389/fpsyg.2014.01003

47. Steinsbekk S, Llewellyn CH, Fildes A, Wichstrom L. Body composition impacts appetite regulation in middle childhood. A prospective study of Norwegian community children. *Int J Behav Nutr Phys Act Vol 14 2017, ArtID 70*. 2017;14. doi:http://dx.doi.org/10.1186/s12966-017-0528-5

48. Steinsbekk S, Wichstrom L. Predictors of Change in BMI From the Age of 4 to 8. *J Pediatr Psychol*. 2015;40(10):1056-1064. doi:https://dx.doi.org/10.1093/jpepsy/jsv052

49. Steinsbekk S, Belsky J, Wichstrom L. Parental feeding and child eating: An investigation of reciprocal effects. *Child Dev*. 2016;87(5):1538-1549. doi:http://dx.doi.org/10.1111/cdev.12546

50. Barkeling B, Ekman S, Rossner S. Eating behaviour in obese and normal weight 11-year-old children. *Int J Obes*. 1992;16(5):355-360.

51. Nisbett RE. Taste, deprivation, and weight determinants of eating behavior. *J Pers Soc Psychol*. 1968;10(2):107-116. doi:10.1037/h0026283

52. Saelens BE, Epstein LH. *Reinforcing Value of Food in Obese and Non-Obese Women*. Vol 27.; 1996.

53. Stunkard AJ, Messick S. The three-factor eating questionnaire to measure dietary restraint, disinhibition and hunger. *J Psychosom Res*. 1985;29(1):71-83. doi:10.1016/0022-3999(85)90010-8

54. Webber L, Hill C, Saxton J, Jaarsveld C, Wardle J. *Eating Behaviour and Weight in Children*. Vol 33.; 2008. doi:10.1038/ijo.2008.219

55. Webber L, Cooke L, Hill C, Wardle J. Child adiposity and maternal feeding practices: a longitudinal analysis. *Am J Clin Nutr*. 2010;92(6):1423-1428. doi:10.3945/ajcn.2010.30112

56. Ventura AK, Birch LL. Does parenting affect children’s eating and weight status? *Int J Behav Nutr Phys Act*. 2008;5:15. doi:10.1186/1479-5868-5-15

57. Mascola AJ, Bryson SW, Agras WS. Picky eating during childhood: a longitudinal study to age 11 years. *Eat Behav*. 2010;11(4):253-257. doi:10.1016/j.eatbeh.2010.05.006

58. Wright C, Birks E. Risk factors for failure to thrive: a population-based survey. *Child Care Health Dev*. 2000;26(1):5-16. doi:10.1046/j.1365-2214.2000.00135.x

59. Galloway AT, Lee Y, Birch LL. Predictors and consequences of food neophobia and pickiness in young girls. *J Am Diet Assoc*. 2003;103(6):692-698. doi:10.1053/jada.2003.50134

60. Gibson EL, Cooke L. Understanding Food Fussiness and Its Implications for Food Choice, Health, Weight and Interventions in Young Children: The Impact of Professor Jane Wardle. *Curr Obes Rep*. 2017;6(1):46-56. doi:10.1007/s13679-017-0248-9

61. Hayes JF, Altman M, Kolko RP, et al. Decreasing food fussiness in children with obesity leads to greater weight loss in family-based treatment. *Obesity*. 2016;24(10):2158-2163. doi:https://dx.doi.org/10.1002/oby.21622

62. Freeman J V, Cole TJ, Chinn S, Jones PR, White EM, Preece MA. Cross sectional stature and weight reference curves for the UK, 1990. *Arch Dis Child*. 1995;73(1):17. http://adc.bmj.com/content/73/1/17.abstract.

63. Mei Z, Grummer-Strawn LM, Pietrobelli A, Goulding A, Goran MI, Dietz WH. Validity of body mass index compared with other body-composition screening indexes for the assessment of body fatness in children and adolescents. *Am J Clin Nutr*. 2002;75(6):978-985. doi:10.1093/ajcn/75.6.978

64. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: International survey. *Br Med J*. 2000. doi:10.1136/bmj.320.7244.1240

65. Cole TJ, Faith MS, Pietrobelli A, Heo M. What is the best measure of adiposity change in growing children: BMI, BMI %, BMI z-score or BMI centile? *Eur J Clin Nutr*. 2005;59(3):419-425. doi:10.1038/sj.ejcn.1602090

66. Hunot C, Fildes A, Croker H, Johnson F, Beeken RJ. Development of a brief Appetitive Trait Tailored Intervention (ATTI) in a sample of overweight and obese adults. In: *34th*

Annual Scientific Meeting of The Obesity Society. ; 2016. https://www.researchgate.net/publication/309720102_Development_of_a_brief_Appetitive_Trait_Tailored_Intervention_ATTI_in_a_sample_of_overweight_and_obese_adults. Accessed April 9, 2020.

67. Hamaker EL, Kuiper RM, Grasman RPPP. A critique of the cross-lagged panel model. *Psychol Methods*. 2015;20(1):102-116. doi:10.1037/a0038889

68. Hunot C, Fildes A, Croker H, Llewellyn CH, Wardle J, Beeken RJ. Appetitive traits and relationships with BMI in adults: Development of the Adult Eating Behaviour Questionnaire. *Appetite*. 2016;105:356-363. doi:10.1016/j.appet.2016.05.024

69. Ryan K, Dockray S, Linehan C. A systematic review of tailored eHealth interventions for weight loss. *Digit Heal*. 2019;5:205520761982668. doi:10.1177/2055207619826685

70. Helle C, Hillesund ER, Wills AK, Øverby NC. Evaluation of an eHealth intervention aiming to promote healthy food habits from infancy -the Norwegian randomized controlled trial Early Food for Future Health. *Int J Behav Nutr Phys Act*. 2019;16(1):1. doi:10.1186/s12966-018-0763-4

71. Boutelle KN, Knatz S, Carlson J, Bergmann K, Peterson CB. An Open Trial Targeting Food Cue Reactivity and Satiety Sensitivity in Overweight and Obese Binge Eaters. *Cogn Behav Pract*. 2017;24(3):363-373. doi:10.1016/j.cbpra.2016.08.003

72. Boutelle KN, Kang Sim DE, Manzano M, Rhee KE, Crow SJ, Strong DR. Role of appetitive phenotype trajectory groups on child body weight during a family-based treatment for children with overweight or obesity. *Int J Obes*. 2019;43(11):2302-2308. doi:10.1038/s41366-019-0463-4

73. Department of Health U, Services H, for Disease Control C. Preventing Chronic Disease, Public Health Research, Practice, and Policy,. doi:10.5888/pcd14.170491

74. Dooyema CA, Belay B, Foltz JL, Williams N, Blanck HM. The childhood obesity research demonstration project: A comprehensive community approach to reduce childhood obesity. *Child Obes*. 2013;9(5):454-459. doi:10.1089/chi.2013.0060

Figure Legends

Figure 1. PRISMA flow diagram describing identification of literature for inclusion in this systematic review and meta-analysis

Figure 2. Part A-H. Pooled effect estimates for unadjusted correlation coefficients with BMI z-scores, by CEBQ scale.

Figure 3. Part A-H. Pooled effect estimates for regression coefficients with BMI z-scores, by CEBQ subscales.

Tables

Table 1. Summary characteristics for cross-sectional CEBQ studies (n=43) included in narrative review.

Author, date	Country	Participants			CEBQ measure		Outcome: weight	CEBQ traits associated with adiposity measures		
		Cohort	N, gender %	Age range/ mean (SD±)	Sub-scales	Language	Measure (reference data)	Positive	Negative	None
Carnell & Wardle, 2008 [a]	UK	TEDS & Community sample	10364, 51.5% F; 572, 46.9% F	8-11 (9.9 ±0.86), 3-5 (4.4±0.62)	EF, SR/SE (combined)[g]	English	BMI z-scores (UK 1990 data)	EF	SR/SE	-
Cao, 2012	China	Community sample	219, 47.9% F	12-18m	EOE, DD[h]	Chinese (Mandarin) [f]	BMI z-scores (Chinese ref data)	-	-	EOE, DD
Bergmeier, 2014	Australia	Community sample	201, 57.7% F	2-5y (2.92 ±0.75)	FF, EF	English	BMI z-scores (CDC)	EF	-	FF
Boswell, 2018 [a]	Australia	Community sample	977, 50.6% F	2-4.9y (3.4 y)	FR, EF, SR, SE, FF	English	BMI z-scores (CDC)	FR, EF	SR, FF	SE
Braden, 2014[b]	USA	Community sample	106, 54.7% F	8-12 (10.34 ±1.31)	EOE	English	BMI percentile (CDC)	-	-	EOE
Brown, 2012	Wales	Community sample	298, NP	18-24m	FR, SR	English	Weight	-	-	FR, SR
Cross, 2014 [a, b]	USA	Community sample	299, 50.3% F	4-5 y	FR, EF, SR	English	BMI z-scores (CDC)	FR, EF	SR	
Demir, 2017	Turkey	Primary school children	1201, (NP)	6-14 y	FR, EF, EOE, DD, SR, SE, FF, EUE	Turkish[3]	BMI (WHO)	FR, EOE, EF	SR, FF	DD, EUE, SE
Domoff, 2015 [a, b]	USA	Appetite, Behavior, and Cortisol [ABC] Cohort + “Growing Healthy” cohort	1002, 50.7% F	4.05 y (0.53±)	FR, EF, EOE, DD, SR, SE, FF, EUE	English	BMI z-scores (CDC)	FR, EF, EOE	SR, SE, EUE, FF	DD
Emond, 2017 [a, b]	USA	Community sample	178, 51.1% F	9-10 y	FR, EF, SR	English	BMI z-scores (CDC)	EF, FR	SR	-
Escobar, 2014 [a, b, d]	Canada	MAVAN	340, 50% F	48-72m	FR, EF, EOE, DD, SR, SE, FF, EUE	English	BMI z-scores	FR, EF, DD, EOE	SR, FF, EUE	SE

Author, date	Country	Participants			CEBQ measure		Outcome: weight	CEBQ traits associated with adiposity measures		
		Cohort	N, gender %	Age range/ mean (SD±)	Sub-scales	Language	Measure (reference data)	Positive	Negative	None
Frankel, 2014 [a]	USA	Head Start Cohort	296, 51% F	4.42 (±0.71)	SR, FR, EF	English + Spanish) [f]	BMI z-scores (CDC)	FR, EF	SR	
Fuemmeler, 2013 [a, b]	USA	AMP Too for Twos	213, 44% F	2.1 (±0.11)	FR, EF, DD, SR/SE[g]	English	BMI z-scores (CDC)	FR, EF, DD	SR/SE	-
Gregory, 2010 [a]	Australia	The Child & Family Health Study		2-4 y; 3.3 (±0.8)	FR[i]	English	BMI z-scores (CDC)	FR	-	-
Hankey, 2016 [a]	USA	Community sample	104, 51% F	3-5 y	SR, FR, EF, EOE	English	BMI z-scores (CDC)	FR, EF	SR	EOE
Hardman, 2016 [a, b]	UK	Community sample	77, 51% F	3-12 y	EOE	English	BMI z-score (WHO)	EOE	-	-
Haycraft, 2011 [a, b]	UK	Community sample	241, 45% F	3-8 y	FR, EF, EOE, DD, SR, SE, FF, EUE	English	BMI z-scores (CGF)	FR, EOE, DD	SE	SR, EUE, FF, EF
Hayes, 2016 [a]	USA	Family- based behavioural treatment	170, 61.2% F	7-11 y (9.41 ±1.23)	FF	English	BMI z-scores (CDC 2000)	-	-	FF
Jansen, 2012 [a]	Netherlands	Generation R cohort	4987, 49.9% F	4 y	FR, EF, EOE, DD, SR, FF, EUE	Dutch [f]	BMI z-scores (Dutch national data)	FR, EF	EUE, SR, FF	EOE, DD
Koch, 2014 [a]	Germany	PIER cohort	1657, 52.1% F	6-11 y	FR, EF, EOE, DD	German	BMI z-scores (German national data)	FR, EOE, DD, EF	-	-
Larsen, 2017 [a]	Netherlands	School-based sample	206, 50.5% F	7-12 y (9.5 ±1.4)	FR	Dutch [f]	BMI z-score (Dutch national data)	FR	-	-
Lipowska, 2018	Poland	Community sample	387, 55.1% F	5 y	FR, EF, EOE, DD, SR, SE, FF, EUE	Polish	BF%	Girls: FR (BF%) Boys: EOE (BF%)	Girls: SR (BF%) Boys: EUE (BF%)	-
Loh, 2013 [a]	Malaysia	Community sample	646, 73.2% F	13 y	FR, EF, EOE, DD, EUE, SE[j]	Malay [f]	BMI z-scores (IOTF)	-	-	EF, EOE, FR, DD, EUE, SE

Author, date	Country	Participants			CEBQ measure		Outcome: weight	CEBQ traits associated with adiposity measures		
		Cohort	N, gender %	Age range/ mean (SD±)	Sub-scales	Language	Measure (reference data)	Positive	Negative	None
Lora, 2016[b]	USA	Community sample	110, 53.6% F	2-5 y	FR, EF, DD	English + Spanish	BMI percentile (CDC)	-	-	FR, EF, DD
Mallan, 2013[e]	Australia	NOURISH cohort	244, 52% F	24 m (1±)	FR, EF, EOE, DD, SR, SE, FF, EUE	English	Weight-for-age z-scores (WHO)	-	SR, SE	FF, EUE, FR, EF, DD, EOE
McPhie, 2011 [a]	Australia	Community sample	175, 53.7% F	2-5 y (2.83 ±0.72)	FF	English	BMI z-scores (IOTF)	-	-	FF
Parkinson, 2010	UK	Gateshead Millennium Study	492 (T1), 583 (T2), 50% F	5-8 y	FR, EF, EOE, DD, SR, SE, FF, EUE	English	BMI	FR, EF	SR, SE, EUE	DD, EOE, FF
Pesch, 2018	USA	Community sample	223, 47.5% F	4-8y	FR, EF, SR [k]	English	BMI z-scores	FR, EF	SR	
Quah, 2017 [a, b]	Singapore	GUSTO	636, 47.8% F	3.06 (±0.1)	SR, SE, DD, EUE, FF[l]	English	BMI z-scores (WHO 2006)	-	SR, SE, EUE	DD, FF
Roach, 2017	USA	The Healthy Family Study	64, 44.3% F	3-6 y	FR, EF, EOE, SR.	English	BMI z-scores (CDC)	FR, EOE, EF	SR	-
Rudy, 2016 [a]	USA	Pre-school sample	181, 48.1% F	4-5 y	FR, SR, EF	English + Spanish [f]	BMI z-scores (CDC)	FR, EF	SR	-
Sanchez, 2016 [a, b]	Chile	GOCS cohort	1058, 51% F	7-10 y	FR, EF, EOE, DD, SR, SE, FF, EUE	Chilean-Spanish [f]	BMI z-scores (WHO)	EF, EOE, FR, DD	SR, SE, FF	EUE
Silva Garcia, 2016 [a, b]	USA	Community sample	186, 47.6% F	4-5 y (4.34 ±0.48)	FR, EF, EOE, DD, SR, SE, FF, EUE	English & Spanish	BMI z-scores (CDC)	FR, EF	SR, SE	EOE, DD, FF, EUE
Sleddens, 2008 [a]	Netherlands	School-based sample	135, 49.6% F	6-7 y	EF, SR, SE, FF[m]	Dutch [f]	BMI z-scores (Dutch national data)	EF	SR, SE	DD, EUE
Somaraki, 2018	Sweden	Swedish Population Registry	Cohort 1: 876,	3-8 yrs	FR, EF, EOE, DD, SR, SE, FF, EUE	Swedish	BMI z-scores (IOTF)	Results stratified by country of origin (n = 74). See original paper for full details.		
		Community sample	Cohort 2: 353,	3-8 yrs						
		Childhood obesity RCT	Cohort 3: 147,	3-8 yrs						

Author, date	Country	Participants			CEBQ measure		Outcome: weight	CEBQ traits associated with adiposity measures		
		Cohort	N, gender %	Age range/ mean (SD±)	Sub-scales	Language	Measure (reference data)	Positive	Negative	None
Soussigan, 2012 [a, b]	France	Community sample	40, 45% F	6-11 y	FR, EOE, DD, SR, SE	French	BMI z-scores (IOTF)	FR, DD	SR, SE	EOE
Svensson, 2011	Sweden	Early STOPP cohort	174, 50% F	1-6 y	FR, EF, EOE, DD, SR, SE, FF, EUE	Swedish [f]	BMI z-scores (French ref data)	-	-	FR, EF, EOE, DD, EUE, FF, SE, SR
Tay, 2016 [a, b]	Malaysia	SEANUTS	1782, 51.4% F	7-12 y	DD, EUE, FF, SE, SR[n]	Malaysian [f]	BMI z-scores (WHO)	DD	SR, SE, FF, EUE	
Viana, 2008 [a]	Portugal	Convenience sample	240, 52% F	3-13 y	FR, EF, EOE, DD, SR, SE, FF, EUE	Portuguese [f]	BMI z-scores (CDC)	FR, EF, EOE	SE, SR, EUE	DD, FF
Vollmer, 2015 [a, b]	USA	Preschool children	150, 45% F	3-5 y	FR, EF, EOE, DD, SR, SE, FF, EUE	English	BMI z-scores (CDC)	FR, EOE	SR	EF, DD, SE, EUE, FF
Webber, 2009 [a, b]	UK	PEACHES	270, 49% F	7-9 y	FR, EF, EOE, DD, SR/SE, FF, EUE[g]	English	BMI z-scores (UK 1990 data)	FR, EOE, EF, DD	SR/SE, FF	EUE
McCarthy, 2015[b, c]	Ireland	The Cork BASELINE birth cohort	1189, 50% F	2 y	FR, EF, EOE, DD, SR, SE, FF, EUE	English	BMI percentiles (WHO)			
Sanlier, 2016[c]	Turkey	Community sample	520, 49% F	2-12 y	FR, EF, EOE, DD, SR, SE, FF, EUE	Turkish	BMI z-scores (WHO)			

Abbreviations: N = Population; SD = Standard Deviation; BMI = Body Mass Index; F = female; FR = Food responsiveness; SR = Satiety responsiveness; EOE = Emotional over-eating; DD = desire to drink; EF = Enjoyment of food; EUE = Emotional under-eating; SE = Slowness in eating; FF = Food fussiness; CDC = Centre for Disease Control; WHO = World Health Organisation; IOTF = International Obesity Task Force; CGF = Child Growth Foundation Reference curves 1996; NP = Not provided; N = Number; y = years. **Cohort acronyms:** Generation R = A population-based birth cohort in the Netherlands followed prospectively; PEACHES = Physical Exercise and Appetite in Children Study; TEDS = Twins Early Development Study; FBBT = Family Based Behavioural Treatment; NOURISH = Intervention/ Randomised Controlled Trial designed to educate paternal feeding practices and promote healthier food intake; The Cork BASELINE Birth Cohort Study = Babies After SCOPE: Evaluating the Longitudinal Impact on Neurological and Nutritional Endpoints Birth Cohort Study; GMS = Gateshead Millennium Study; GOCS = Growth and Obesity Chilean Cohort Study; TESS = Trondheim Early Secure Study; Healthy You! University of Minnesota Masonic Children's Hospital Pediatric Weight Management Clinic; ABCD = Amsterdam Born Children and their Development cohort.

[a] Indicates studies included in the meta-analysis

[b] Indicates studies for which authors provided additional data.

[c] Indicates studies where data were analysed using logistic regression, and the results were presented as odds ratios.

[Sanlier et al (2018) used multiple logistic regression models for the association between CEBQ scales and BMI z-scores, stratified by weight status: FF was significant negatively associated in the overweight (B = -.54, p=.01) and obese weight category (B = -.058, p<.01). EF was significantly positively associated (B = .65, p=.04) in the normal weight category. All other traits were null associations. McCartney et al. (2015) reported odds ratio (OR) for overweight/obesity by CEBQ traits; EF (OR =1.90, 95% confidence interval (CI)=1.46–2.48), FR (OR=1.73, 95% CI=1.47–2.03; all p<0.001), SR (OR=0.56, 95% CI = 0.43-0.73; p<.001), SE (OR = 0.57, 95% CI = 0.45, 0.73; p<.001), FF (OR = 0.70, 95% CI = 0.56-0.88; p=0.002). EUE, EOE, DD not significant.]

[d] Escobar et al (2014) data presented in the table are for baseline results at 48 months.

[e] Data reported in Mallan et al (2014) were taken from both the intervention and control groups of NOURISH. The intervention group received education sessions aimed to improve parental feeding practices and influence infants' food intake and eating habits. It is therefore important to note that the results presented could be influenced by the effect of intervention.

[f] Denotes validated translated versions of the CEBQ.

Modifications to CEBQ subscales (scales that were modified from original format were excluded from review)**

[g] SR + SE combined

[h] FR split into two scales. One SE item dropped. 3 FF items dropped. SR dropped.

[i] FF scale split into two

[j] FF split in two, with 2 SR items added in FF1

[k] SR reverse scored

[l] FR, EOE and EF subscales changed.

[m] EOE+FR combined to new EOE scale

[n] 1 item dropped from EOE & items moved from EOE, EF into FR

Table 2. Summary characteristics for cross-sectional studies comparing mean CEBQ scale scores across weight categories and testing for linearity of trends (n=19)

Author, date	Country	Participants			CEBQ measure		Outcome: weight	
		Cohort	N, Gender % F	Age range/ mean (SD±)	Sub-scales	Language	Measure (reference data)	Weight categories used
Carnell & Wardle, 2008 [a, b]	UK	TEDS & Community sample	10364, 51.5% F; 572, 46.9% F	8-11 (9.9 ±0.86), 3-5 (4.4 ±0.62)	EF, SR/SE (combined)[e]	English	BMI z-scores (UK 1990 data)	Low-normal, mid-norm, high, very high
Boswell, 2018 [a, b]	Australia	Community sample	977, 50.6% F	2-4.9y (3.4 y)	FR, EF, SR, SE, FF	English	BMI z-scores (CDC)	UW, NW, OW, OB
Croker, 2011	UK	PEACHES & TEDS; FBBT sample	406, 54% F; 66, 68% F	7-12 y; 8-13 y	FR, EF, EOE, DD, SR/SE, FF, EUE[e]	English	BMI z-scores (UK 1990 data)	UW, NW, OW, OB, Clinically OB
de Groot, 2017	Netherlands	Community sample	44, 50%	12-16y	FR, SR, EF, EOE, DD	Dutch	BMI SDS (NP)	NW, OW
dos Passos, 2015	Brazil	Community sample	335, 51.3% F	6-10 y (7.33 ±0.87)	FR, EF, EOE, DD, SR, SE, EUE, FF	English	BMI z-scores (WHO)	NW, OW, OB, Severe OB
Gardner, 2015	USA	Community sample	64, 49.4% F)	5-6 y	FR, EF, SR	English	BMI-for-age percentile (CDC 2000)	NW, OB
Ho-Urriola, 2014	Chile	Community sample	377, 51.3% F	6-12 y (10.1 ±2)	FR, EF, EOE, DD, SR, SE, EUE, FF	Chilean	BMI percentiles (CDC 2000)	NW, OB
Jahnke, 2008	Germany	Community sample	142, 36% F	3-6 y (4.2 ±1)	FR	German	BMI z-scores (German national data)	UW, NW, OW, OB
McCarthy, 2015 [a, b]	Ireland	The Cork BASELINE birth cohort	1189, 50% F	2 y	FR, EF, EOE, DD, SR, SE, FF, EUE	English	BMI percentiles (WHO)	UW, NW, OW/OB
Mosli, 2015	USA	Community sample	274, 49.3% F	4-8 y	SR, SE, FF	English	BMI percentiles (CDC 2000)	NW (<85th), OW/OB (85th>)

Obregon, 2017	Chile	Community sample	258, 44% F	8-14 y (11.4 ±1.6)	FR, EF, EOE, DD, SR, SE, EUE, FF	Chilean	BMI percentiles (CDC 2000 + WHO 2006)	NW, OW, OB
Parkinson, 2010 [a, b, c]	UK	Gateshead Millennium Study	492 (T1), 583 (T2), 50% F	5-8 y	FR, EF, EOE, DD, SR, SE, FF, EUE	English	BMI	BMI centile lowest, middle, highest
Powers, 2016	USA	Community sample	296,48% F	2-5y	FR[f]	English	BMI z-scores (CDC)	UW, NW, at-risk for OW, OW
Sanchez, 2016[a, b]	Chile	GOCS cohort	1058, 51% F	7-10 y	FR, EF, EOE, DD, SR, SE, FF, EUE	Chilean-Spanish[d]	BMI z-scores (WHO)	NW, OW, OB
Soussigan, 2012 [a, b]	France	Community sample	40, 45% F	6-11 y	FR, EOE, DD, SR, SE	French	BMI z-scores (IOTF)	NW, OW
Spence, 2011	Canada	Community sample	1730, 48.9% F	4-5 y	FR, EF, EOE, DD, SR, SE, FF, EUE	English	BMI (CDC + IOTF classification)	UW, NW, at-risk for OW, OW
Webber, 2009[a, b]	UK	PEACHES	270, 49% F	7-9 y	FR, EF, EOE, DD, SR/SE, FF, EUE[e]	English	BMI z-scores (UK 1990 data)	Thinness grade 1/2, low NW 50th centile or less, mid normal weight >50th but not OW, OW/OB
Sandvik, 2018	Sweden	Swedish Registry sample	1272, 47% F	3.3-7.9y (4.9 ±0.8)	FR, EF, EOE, DD, SR, SE, FF, EUE	Swedish	BMI z-scores (IOTF)	Thinness (BMI <18.5kg/m^2), NW, OW, OB
Sanlier, 2016 [c]	Turkey	Community sample	520, 49% F	2-12 y	FR, EF, EOE, DD, SR, SE, FF, EUE	Turkish	BMI z-score (WHO)	UW, NW, OW, OB

[a] Indicates studies also reporting continuous associations between CEBQ and adiposity; these are included in this section of the narrative review.
[b] Indicates studies included in the meta-analysis.
[c] Indicates the study also reporting prospective association between CEBQ and adiposity.
[d] Denotes validated translated versions of the CEBQ.
[e] SR + SE combined
Modifications to CEBQ subscales (scales that were modified from original format were excluded from review)**
[f] DD item dropped

Abbreviations: N = Population; SD = Standard Deviation; BMI = Body Mass Index; F = female; FR = Food responsiveness; SR = Satiety responsiveness; EOE = Emotional over-eating; DD = desire to drink; EF = Enjoyment of food; EUE = Emotional under-eating; SE = Slowness in eating; FF = Food fussiness; CDC = Centre for Disease Control; WHO = World Health Organisation; IOTF = International Obesity Task Force; NP = Not provided; y = years;
Cohort acronyms: TEDS = Twins Early Development Study; GOCS = Growth and Obesity Chilean Cohort Study; PEACHES = Physical Exercise and Appetite in Children Study; FBBT = Family Based Behavioural Treatment

Table 3. Summary characteristics for prospective studies examining associations between CEBQ scales at baseline and later adiposity (n=11)

Author, date	Country	Participants			CEBQ measure		Outcome: adiposity measure	Associations between CEBQ scales and later adiposity (CEBQ → adiposity)		
		Cohort	N, gender %	Age range/ mean (SD±)	Sub-scales	Language	Measure (reference data)	Significant Positive	Significant Negative	Null
Mallan, 2016[a]	Australia	NOURISH	340, F 53.5%	14m - 3.7y	FF	English	BMI z-scores (WHO)		FF	
Mallan, 2014[a]	Australia	NOURISH	37[f] (Control n=20, Intervention n =17), 57% F	2-4 y	FR, EF, SR, SE	English	BMI z-scores (WHO)		SR	FR, EF, SE
McPhie, 2012[b]	Australia	Community sample	117, F 53.8%	2-5 y	FF[i]	English	BMI z-scores (CDC)			FF
Quah, 2015[c]	Malaysia	GUSTO	210 (T2 = 205, T3 = 162, T4 = 179), F 49.5%	12-24m	SR, SE[j]	Malaysian[h]	BMI z-scores (WHO)			SR, SE
Steinsbekk, 2015	Norway	TESS	996 (T1=4y) 658 (T2=6y) 675 (T3=8y)	4-8 y	FR, EF, EOE, SR, SE	Norwegian[h]	BMI z-scores	FR, EF, EOE	SR, SE	
Derks, 2018[d]	Netherlands	Generation R	3514, (T1- 4y) 3097, (T2- 6y) 3331, (T3- 9.8y), F 51.3%	4-10 y	FR, EOE, EF, SR/SE[k]	Dutch[h]	BMI z-scores, FMI, FFMI (Dutch growth reference curves)	EOE		FR, EF, SR
Steinsbekk, 2017[d, e]	Norway	TESS	807, F 50.2%	6-10 y	FR, SR	Norwegian[h]	BF%, MM%	FR (BF%)	SR (BF%)	
Bjorklund, 2018[e]	Norway	TESS	797 (T1 - 6.7y) 699 (T2 - 8.8y) 702 (T4 - 10.5y), F 50.2%	6-10 y	FR	Norwegian[h]	BMI z-scores	FR		
Bergmeier, 2014	Australia	Community sample	201, F 56.7%	2-5 y	FF, EF	English	BMI z-scores (CDC)			FF, EF
Escobar, 2014[e, f, g]	Canada	MAVAN	340 (48m), 278 (60m), 221	48-72m	FR, EOE, DD, EF, EUE, SE, SR, FF	English	BMI z-scores	FR, EF, DD, EOE	SR, SE	FF, EUE

			(72m), F 54.1%							
Parkinson, 2010	UK	GMS	492 (5-6y) 583 (6-8y)	6-8 y	FR, EOE, DD, EF, EUE, SE, SR, FF	English	BMI percentiles (Cohort mean)	FR, EOE, EF, DD	SR, SE	EUE, FF

Abbreviations: N = Population; SD = Standard Deviation; BMI = Body Mass Index; F = female; FR = Food responsiveness; SR = Satiety responsiveness; EOE = Emotional over-eating; DD = desire to drink; EF = Enjoyment of food; EUE = Emotional under-eating; SE = Slowness in eating; FF = Food fussiness; CDC = Centre for Disease Control; WHO = World Health Organisation; IOTF = International Obesity Task Force; NP = Not provided; y = years; FMI = Fat Mass Index, FFMI = Fat Free Mass Index.

Cohort acronyms: Generation R = A population-based birth cohort in the Netherlands followed prospectively; NOURISH = Intervention/ Randomised Controlled Trial designed to educate paternal feeding practices and promote healthier food intake GMS = Gateshead Millennium Study; TESS = Trondheim Early Secure study; ABCD = Amsterdam Born Children and their Development cohort

[a] Data for Mallan et al (2014, 2016) were taken from both the intervention and control groups of NOURISH. The intervention group received education sessions aimed to improve parental feeding practices and influence infants' food intake and eating habits. It is therefore important to note that the results presented could be influenced by the effect of intervention.

[b] EF subscale result reported in paper, but subscale coding was modified in McPhie et al (2012). Results for EF have been excluded. Association between FF and BMI z-score in this study are based on change in FF with change in BMI z-score.

[c] Quah et al (2015) merged the FR & EF subscales, these observations have been excluded from the table above.

[d] Indicates studies that reported on the bidirectional relationship between appetite and adiposity.

[e] When multiple time waves of data are presented at the individual study level, the longest time period is summarised in the table above.

[f] Authors provided additional data.

[g] Prospective associations presented for the MAVAN cohort (Escobar et al, 2014) are based on additional data obtained from the study authors for all CEBQ subscales (results presented are for BMI z-score at 48m to CEBQ measured at 72 m).

[h] Denotes validated translated versions of the CEBQ.

Modifications to CEBQ subscales (scales that were modified from original format were excluded from review)**

[i] EF item dropped from scale

[j] FR and EF subscales adapted

[k] SR/SE combined

Table 4. Summary characteristics for CEBQ prospective studies (n=5) reporting on relationship between adiposity and later appetite

Author, date	Country	Direction	Participants			CEBQ measure		Outcome: adiposity measure (reference data)	Adiposity associated with CEBQ		
			Cohort	N, gender %	Age range	Sub-scales	Language		Positive	Negative	None
Steinsbekk, 2015	Norway	BMI → CEBQ	TESS	996 (T1=4y) 658 (T2=6y) 675 (T3=8y)	4-8 y	FR, EF, EOE, SR, SE	Norwegian[c]	BMI z-score	FR	SR	EF, SE, EOE
Steinsbekk, 2016	Norway	BMI → CEBQ	TESS	797[k], 50.2% F	6-8 y	FR, EF, EOE, SR, SE	Norwegian[c]	BMI z-scores	FR	SR	EF, SE, EOE
Derks, 2018[d]	Netherlands	BMI → CEBQ	Generation R	3514, (T1- 4y) 3097, (T2- 6y) 3331, (T3- 9.8y), F 51.3%	4-10 y	FR, EOE, EF, SR/SE[f]	Dutch[c]	BMI z-scores, FMI, FFMI (Dutch growth reference curves)	FR, EOE, EF	SR	
Steinsbekk, 2017[d]	Norway	BF% → CEBQ	TESS	807, F 50.2%	6-10 y	FR, SR	Norwegian[c]	BF%, MM%	FR (BF%)	SR (BF%)	
van Deutekom, 2016[a, b]	Netherlands	Δ weight-for-age z-score → CEBQ	ABCD	2227, F 48.7%	0-5 y	SR	Dutch[c]	Weight-for-age z-scores (Study population)		SR 0-1m, 1-3m, 3-6m, 6-12m, 12-5 y.	Birth weight

Abbreviations: N = Population; BMI = Body Mass Index; F = female; FR = Food responsiveness; SR = Satiety responsiveness; EOE = Emotional over-eating; DD = desire to drink; EF = Enjoyment of food; EUE = Emotional under-eating; SE = Slowness in eating; FF = Food fussiness; y = years; FMI = Fat Mass Index, FFMI = Fat Free Mass Index.
Cohort acronyms: Generation R = A population-based birth cohort in the Netherlands followed prospectively; TESS = Trondheim Early Secure study; ABCD = Amsterdam Born Children and their Development cohort

[a] van Deutekom et al (2016) reported on the relationship of conditional weight gain to SR.
[b] Authors provided additional data.
[c] Denotes validated translated versions of the CEBQ.
[d] Indicates studies that reported on the bidirectional relationship between adiposity and appetite.
[f] SR/SE combined

Table 5. Summary characteristics for BEBQ cross-sectional and prospective studies (n = 5) included in the narrative review.

Author, date	Country	Design	Participants			BEBQ measure		Outcome: weight	BEBQ traits associated with weight		
			Cohort	N, gender %	Age range/ mean (SD±)	Sub-scales	Language	Measure (reference data)	Positive	Negative	None
Mallan, 2014	Australia	Prospective	New Beginnings: Healthy Mothers and Babies Study	467, F 50%	4 m (±0.6)	FR, EF, SE, SR	English	BMI, Weight-for -age z-score (WHO)	EF	SR, SE	FR
Quah, 2015	Singapore	Prospective	GUSTO	210, F 50.5%	0-24 m	EF, FR, SE/SR[a]	English	BMI z-scores (WHO)	FR	SE/SR	EF
Shepard, 2015	USA	Prospective	Community	31, F 39%	0.5-5 m	EF, FR, SE, SR, GA	English	BMI z-scores (WHO)	EF, FR, GA	SE	SR
van Jaarsveld, 2011	UK	Prospective	Gemini	4804, F 50.3%	3-15 m/8.2 m (±2.2)	EF, FR, SE, SR, GA	English	BMI z-scores (UK 1990 data)	EF, FR, GA	SR, SE	
Patel, 2018	UK	Cross-sectional	UPBEAT	353	6 m	SE, FR, EF, GA	English	BMI z-scores (WHO)	GA		SE, FR, EF

Abbreviations: N = Population; SD = Standard Deviation; BMI = Body Mass Index; F = female; FR = Food responsiveness; SR = Satiety responsiveness; EF = Enjoyment of food; SE = Slowness in eating; GA = General Appetite; WHO = World Health Organisation; m = months
Cohort acronyms: GUSTO = Growing Up in Singapore Toward healthy Outcomes, UPBEAT = UK Pregnancies Better Eating and Activity Trial.

[a] SR + SE combined

Table 6. Results from random effects meta-analysis of studies examining correlation of CEBQ scales with BMI z-scores (only unadjusted correlation coefficients[a])

CEBQ scale	r	95 % CI	I^2 (%)	P-value for heterogeneity	Sub-cohorts (n)	n
FR	0.22	(0.16, 0.29)	88.0	0.00	19	9463
EF	0.17	(0.14, 0.20)	49.4	0.00	19	20416
EOE	0.15	(0.08, 0.22)	82.9	0.00	11	7038
DD	0.10	(0.04, 0.15)	82.9	0.00	10	9219
SR	-0.21	(-0.24, -0.17)	56.7	0.00	17	9854
SE	-0.15	(-0.21, -0.10)	64.8	0.00	8	5192
FF	-0.08	(-0.10, -0.06)	0.00	0.99	11	8855
EUE	-0.09	(-0.11, -0.06)	8.00	0.37	7	7330

[a]Data for Haycraft et al (2011) were reported as adjusted in the original study. Authors provided raw data to calculate the unadjusted correlation coefficients, and these were subsequently were pooled in the model presented above.

Table 7. Results from random effects meta-analysis of studies examining regression of BMI z-scores on CEBQ scales, stratified by level of adjustment

CEBQ scale	β	95 % CI	I^2 (%)	P-value for heterogeneity	Sub-cohorts (n)	n
Overall						
FR	**0.21**	(0.13, 0.28)	89.9	0.00	13	8284
EF	**0.20**	(0.12, 0.27)	90.9	0.00	15	8715
EOE	**0.22**	(0.13, 0.31)	87.2	0.00	12	4149
DD	0.03	(-0.03, 0.08)	73.4	0.00	11	6020
SR	**-0.33**	(-0.40, -0.23)	94.0	0.00	14	9800
SE	**-0.19**	(-0.25, -0.12)	85.6	0.00	12	6889
FF	-0.04	(-0.08, 0.01)	76.0	0.00	15	10053
EUE	**-0.04**	(-0.08, -0.01)	48.0	0.03	13	9339
Crude-only						
FR	**0.19**	(0.11, 0.27)	83.4	0.00	7	5734
EF	**0.20**	(0.12, 0.28)	86.8	0.00	8	6030
EOE	**0.20**	(0.08, 0.32)	88.9	0.00	6	4621
DD	-0.07	(-0.28, 0.14)	96.8	0.00	5	4653
SR	**-0.30**	(-0.42, -0.17)	94.5	0.00	7	5817
SE	**-0.13**	(-0.20, -0.06)	51.0	0.00	4	2260
FF	-0.04	(-0.10, 0.02)	67.1	0.01	6	5630
EUE	**-0.05**	(-0.12, 0.03)	68.9	0.02	4	4440
Adjusted-only						
FR	**0.22**	(0.11, 0.34)	93.2	0.00	7	5707
EF	**0.18**	(0.07, 0.30)	93.1	0.00	8	5842
EOE	**0.20**	(0.09, 0.32)	88.1	0.00	7	2685
DD	0.04	(-0.03, 0.11)	78.1	0.00	7	4524
SR	**-0.31**	(-0.41, -0.22)	93.3	0.00	8	7140
SE	**-0.21**	(-0.31, -0.11)	89.5	0.00	8	4629
FF	-0.05	(-0.11, 0.01)	79.6	0.00	10	7580
EUE	**-0.05**	(-0.09, -0.02)	45.7	0.06	10	8056

Pooled effect estimates are presented by level of study adjustment reported at the individual study level.
The 'Overall' pooled model exclusively includes observations from the maximum number of studies, primarily including adjusted estimates for studies that provided such data. If not available, then unadjusted data were included.
The 'Crude-only' model exclusively includes observations from any study that provided unadjusted data.
The 'Adjusted-only' model exclusively includes observations from any study that provided unadjusted data.
Statistically significant estimates have been bolded.