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Weight, appetitive behaviours and parental feeding practices in childhood: their association and reciprocal influences

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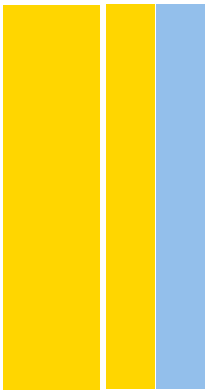

Weight, appetitive behaviours and parental feeding practices in childhood: their association and reciprocal influences

Alexandra Ferreira da Costa

Dissertação de candidatura ao grau de Mestre em Saúde Pública apresentada à Faculdade de Medicina da Universidade do Porto e ao Instituto de Ciências Biomédicas Abel Salazar.

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Departamento de Ciências da Saúde Pública e Forenses e Educação Médica da Faculdade de Medicina da Universidade do Porto

O presente trabalho foi elaborado no âmbito da coorte Geração XXI e desenvolvido no Departamento de Ciências da Saúde Pública e Forenses, e Educação Médica da Faculdade de Medicina da Universidade do Porto e no Instituto de Saúde Pública da Universidade do Porto.

A sua realização só foi possível com a participação das crianças e famílias que aceitaram este desafio, às quais agradecemos a sua disponibilidade. A Coorte Geração XXI foi financiada pelo Programa Operacional de Saúde – Saúde XXI, Quadro Comunitário de Apoio III, pela Administração Regional de Saúde do Norte, pela Fundação Calouste Gulbenkian e pela Fundação para a Ciência e a Tecnologia.

Os objetivos desta dissertação inserem-se em projetos de investigação financiados por Fundos FEDER através do Programa Operacional Fatores de Competitividade – COMPETE e por Fundos Nacionais através da FCT – Fundação para a Ciência e Tecnologia: "Appetite regulation and obesity in childhood: a comprehensive approach towards understanding genetic and behavioral influences" (POCI-01-0145-FEDER-030334; PTDC/SAU-EPI/30334/2017) and "Appetite and adiposity - evidence for gene-environment interplay in children" (IF/01350/2015).

Esta dissertação tem por base três manuscritos, nos quais colaborei ativamente na formulação das hipóteses, análise dos dados e interpretação dos resultados e fui responsável pela escrita das primeiras versões:

- Bidirectional relationships between appetitive behaviours and body mass index in childhood: a cross‐lagged analysis in the Generation XXI birth cohort.
- Relationships between parental feeding practices and eating behaviours in childhood: a cross-lagged approach within the Generation XXI cohort.
- Maternal perception, concern and dissatisfaction with child weight and their association with feeding practices in the Generation XXI birth cohort.

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ABBREVIATION LIST

BMI (Body Mass Index)

Child Feeding Questionnaire (CFQ)

Children's Eating Behaviour Questionnaire (CEBQ)

Cholecystokinin (CCK)

Gene-wide association studies (GWAS)

Glucagon-like peptide-1 (GLP-1)

Peptide tyrosine tyrosine (PYY)

World Health Organization (WHO)

RESUMO

INTRODUÇÃO E OBJETIVOS

A Teoria da Suscetibilidade Comportamental propõe que o desenvolvimento da obesidade resulta da combinação entre uma suscetibilidade genética para um consumo alimentar excessivo e a exposição a um ambiente obesogénico. Os comportamentos alimentares relacionados com o apetite têm sido associados ao Índice de Massa Corporal (IMC) e parecem ter uma forte componente gética. No entanto, são necessários estudos longitudinais e com abordagens mais robustas para suportar esta teoria. Apesar da forte hereditariedade, vários fatores ambientais têm sido apontados como determinantes na expressão dos comportamentos alimentares relacionados com o apetite. Os pais, como principais responsáveis pelo ambiente alimentar da criança, poderão ter um papel fundamental. Alguns estudos demonstraram que práticas alimentares não responsivas podem afetar negativamente os comportamentos alimentares da criança. Este tipo de práticas pode, potencialmente, comprometer a capacidade de autorregulação impedindo que a criança responda de uma forma adequada aos sinais internos de fome ou saciedade. É importante ter em consideração que a relação entre as práticas parentais e os comportamentos alimentares é complexa, uma vez que os pais usam diferentes estratégias em resposta às características das crianças e de acordo com suas crenças e aprendizagens.

Esta tese tem como objetivo estudar a associação entre o peso e os comportamentos alimentares relacionados com o apetite e perceber qual o papel das práticas parentais no desenvolvimento destes comportamentos, assim como, compreender de que forma os pais respondem às caraterísticas das crianças no contexto da alimentação. Para responder a este objetivo principal, foram definidos três objetivos específicos: 1) estudar as relações bidirecionais entre os comportamentos alimentares relacionados com o apetite e o IMC, dos 7 aos 10 anos (artigo I); 2) analisar as associações bidirecionais entre as práticas parentais relacionadas com a alimentação e os comportamentos alimentares das crianças dos 4 aos 7 anos de idade (artigo II); 3) estudar de que forma a perceção, preocupação e insatisfação materna com o peso da criança

estão associadas às práticas relacionadas com a alimentação aos 4 anos e três anos mais tarde (artigo III).

MÉTODOS

Este estudo incluiu participantes da coorte de nascimentos de base populacional Geração XXI. Entre abril de 2005 e agosto de 2006, foram recrutados 8647 nados vivos nas maternidades públicas da área metropolitana do Porto. Todas as famílias foram convidadas para participar em novas avaliações quando as crianças tinham 4, 7 e 10 anos de idade (proporção de participação de 86%, 80% e 74%, respetivamente). Aos 7 e 10 anos de idade, o *Children's Eating Behaviour Questionnaire* (CEBQ) foi usado para avaliar os comportamentos alimentares relacionados com o apetite (8 subescalas: Resposta aos Alimentos, Prazer em Comer, Sobre-ingestão Emocional, Desejo por Bebidas, Resposta à Saciedade, Ingestão Lenta, Sub-ingestão Emocional, Seletividade Alimentar), previamente validado nesta população. Adicionalmente, aos 4 e 7 anos de idade, os comportamentos alimentares das crianças foram avaliados de acordo com a perceção dos pais: comer muito devagar, comer grandes quantidades de alimentos (questões dicotómicas) e recusa alimentar (variável combinada com base na recusa em comer frutas e produtos hortícolas, sopa e peixe). As práticas parentais relacionadas com a alimentação da criança foram avaliadas com uma versão validada do *Child Feeding Questionnaire* (CFQ) e a da escala de Overt/Covert Control. Estas práticas foram sumariadas, através de análise de componentes principais, em três padrões (Monitorização Percebida, Restrição e Pressão para Comer). As mães reportaram a sua perceção, insatisfação e nível de preocupação com o ganho de peso da criança, usando uma escala de *Likert*. Foi realizada uma avaliação antropométrica das crianças, em todas as avaliações, por investigadores treinados utilizando procedimentos padronizados. Os scores de desvio padrão de IMC específicos para idade e sexo (IMC z-score) foram calculados de acordo com a referência de crescimento da Organização Mundial da Saúde para crianças em idade escolar.

Foram realizadas análises de caminhos cruzados para comparar a magnitude e direção das diferentes associações em estudo (artigos I e II). A associação entre perceção, preocupação e insatisfação materna com o peso da criança e práticas relacionadas com a alimentação foi avaliada por modelos de regressão linear (artigo III). Os coeficientes de

regressão β̂ e os respetivos intervalos de confiança a 95% ou 99,4% (IC%) foram calculados para cada estudo, após ajuste para os potenciais confundidores.

RESULTADOS

No artigo I, na análise de caminhos cruzados, verificou-se que os comportamentos alimentares relacionados com o apetite desenvolvidos aos 10 anos foram reativos ao z-score de IMC da criança aos 7 anos (com exceção de Sub-ingestão Emocional). Apenas o domínio Ingestão Lenta foi significativamente associado com o IMC subsequente; no entanto, a direção mais forte foi no sentido z-score de IMC para o comportamento (β̂padronizado= -0,028; 99,4%IC = -0,049, -0,007 em comparação com β̂padronizado= -0,103; 99,4%IC= -0,138, -0,069; teste da razão de verossimilhança: p <0,001) (co-variáveis: sexo da criança, exercício físico, idade e escolaridade maternas e z-score de IMC aos 7 anos ou, no sentido inverso, a pontuação da subescala em análise).

No artigo II, na análise de caminhos cruzados, comer grandes quantidades de alimentos aos 4 anos foi unidireccionalmente associado a uma maior Restrição três anos mais tarde (β̂padronizado= -0,047; IC95% = -0,019, -0,075). Além deste resultado, todas as associações tiveram um efeito bidirecional de magnitude semelhante. Comer grandes quantidades de alimentos, comer muito devagar e a recusa de alimentos aos 4 anos influenciaram os pais a usarem determinadas práticas de controlo alimentar, como Monitorização Percebida ou Pressão para comer, aos 7 anos. No entanto, estas práticas também influenciaram o desenvolvimento destes comportamentos alimentares (por exemplo, β̂padronizado= 0,033; IC95% = 0,022,0,064 para recusa alimentar aos 4 anos e Pressão para Comer aos 7 anos e β̂padronizado= 0,060; IC95% = 0,034, 0,086, no sentido inverso) (co-variáveis: sexo da criança e IMC aos 4 anos de idade, escolaridade da mãe a pontuação do padrão ou comportamento alimentar aos 4, de acordo com a direção analisada).

No artigo III, verificou-se que uma grande percentagem das mães que tinham filhos com excesso de peso ou obesidade não conseguiam identificar esta condição (83,8% aos 4 e 70,3% aos 7 anos). Após ajuste para escolaridade materna, sexo da criança e IMC, a perceção de baixo peso foi associada a práticas que promovem a ingestão alimentar, como maior Pressão para Comer aos 4 e 7 anos de idade (β̂=0,234, IC95%:

0,243, 0,486 e β̂=0,329, IC95%: 0,199, 0,459, respetivamente) e menor Restrição aos 7 (β̂=-0,114, IC95%: -0,217, -0,010). A perceção do peso da criança como excessivo foi consistentemente associada às práticas parentais relacionas com a alimentação aos 7 anos de idade, incluindo: Controlo Encoberto (β̂=0,279, IC95%: 0,170, 0,389), Controlo Explicito (β̂=-0,081; IC95%: -0,157, -0,006), Pressão para Comer (β̂=-0,272, IC95%: -0,401, -0,143) e Monitorização (β̂=-0,102; IC95%: -0,193, -0,010). As mães preocupadas com o ganho de peso da criança reportaram níveis mais elevados de Restrição (β̂=0,241 IC95%: 0,178,0,300 e β̂=0,279, IC95%: 0,206,0,339 aos 4 e 7 anos, respetivamente) e Controlo Encoberto (β̂=0,187, IC95%: 0,112, 0,261 e β̂=0,185, IC95%: 0,113, 0,257, respetivamente). As mães que desejavam que os filhos tivessem mais peso reportaram níveis mais elevados de Pressão para Comer, enquanto que as mães que desejavam que os filhos fossem mais magros usavam menos Pressão e Monitorização (β̂=-0,320, IC95%: -0,465, -0,174 aos 4 anos e β -0,142, IC95%: -0,269, -0,015 aos 7 anos).

Conclusões

As crianças com um IMC mais elevado na infância apresentam um risco superior de desenvolver um apetite mais ávido ao longo do tempo. As associações mais fortes observadas foram no sentido do IMC aos 7 anos influenciar os comportamentos alimentares relacionadas com o apetite desenvolvidos aos 10 anos e não no sentido inverso. As práticas parentais relacionadas com a alimentação e os comportamentos alimentares das crianças associam-se de uma forma bidirecional, o que indica que pais e filhos influenciam reciprocamente o comportamento um do outro. Os pais são, também, influenciados pelas suas perceções e preocupações com o peso das crianças nas práticas alimentares que utilizam. Estes resultados evidenciam a complexidade da dinâmica entre pais e filhos no que diz respeito à alimentação.

As conclusões deste trabalho podem ser úteis em investigação futura, assim como contribuir para o desenvolvimento de estratégias de intervenção, baseadas na evidência, que visem orientar os pais sobre como alimentar os seus filhos de uma forma que otimize a saúde infantil.

ABSTRACT

Background and Aims

The Behavioural Susceptibility Theory proposes that obesity develops from a combination of genetic susceptibility to overeating and exposure to an obesogenic environment. Appetitive behaviours have been associated with Body Mass Index (BMI) and appear to have a substantial genetic underpinning; however, longitudinal and more robust approaches are lacking to fully support this theory. Despite the strong heritably, several environmental factors have been pointed out as key drivers in the expression of appetitive behaviours. Parents, as the main responsible for the child's early food environment, might have an important role. Some studies have emphasized the negative interference of nonresponsive feeding practices on child's appetitive behaviours, hypothesising that they may disrupt their ability to self-regulate and respond appropriately to internal cues of hunger or fullness. However, the relationship between parental feeding practices and children's behaviours is complex, as parents use specific feeding strategies in response to the characteristics of the children and according to their cognitions and beliefs.

This thesis aims to study the association between weight and appetite behaviours and the role of parental feeding practices in the development of these behaviours, as well as how parents respond to the children's characteristics in the context of feeding. To answer this main goal, three specific objectives were defined: 1) to analyse the bidirectional relationships between appetitive behaviours and BMI from 7 to 10 years of age (paper I); 2) to examine the bidirectional associations between parental feeding practices and eating behaviours from 4 to 7 years of age (paper II); 3) to study how maternal perception, concern and dissatisfaction with child weight are associated with feeding practices at 4 years of age and three years' later (paper III).

Methods

This research included participants from the population-based birth cohort, Generation XXI. A total of 8647 liveborn infants were enrolled between April 2005 and

August 2006 in public maternity wards from the metropolitan area of Porto. All families were invited to attend evaluations when children were aged 4, 7 and 10-years-old (86%, 80%, and 74% participation proportion, respectively). At 7 and 10 years of age, the Children's Eating Behaviour Questionnaire (CEBQ) was used to measure appetitive behaviours (8 subscales: Food Responsiveness, Enjoyment of Food, Emotional Overeating, Desire to Drink, Satiety Responsiveness, Slowness in Eating, Emotional Undereating, Food Fussiness), previously validated in this population. Additionally, at 4 and 7 years old, children's eating behaviours were evaluated according to parent's perception: eating very slowly, eating large amounts of food (dichotomous questions) and food refusal (a combined variable was created based on refuse to eat fruits and vegetables, soup and fish). Parental feeding practices were assessed with a validated version of the Child Feeding Questionnaire (CFQ) and the Overt/Covert Control scale. Parental feeding practices were summarized by principal component analysis, into three patterns (Perceived Monitoring, Restriction, and Pressure to eat). Mothers self-reported their perception, level of concern about weight gain and dissatisfaction with child weight using a Likert scale. Child's anthropometrics were measured at all ages by trained staff using standard procedures and age- and sex-specific BMI standard deviation scores (BMI z-scores) were computed according to the World Health Organization Growth Reference for school-aged children.

Cross-lagged analyses were performed to compare the magnitude and direction of the different associations under study (papers I and II). The association between maternal perception, concern and dissatisfaction with child weight and feeding practices were evaluated by linear regression models (paper III). $\hat{\beta}$ regression coefficients and the respective 95% or 99.4% confidence intervals (CI) were computed for each study, after adjustment for potential confounders.

RESULTS

In paper I, in cross-lagged analyses, appetitive behaviours at 10 years of age were shown to be reactive to the child BMI z-score at 7 years of age (apart from Emotional Undereating). Only Slowness in eating was significantly related to subsequent BMI. However, the strongest path was from the child BMI z-score to the behaviour

(β̂standardized= -0.028; 99.4%CI= -0.049, -0.007 compared with β̂standardized= -0.103; 99.4%CI= -0.138, -0.069; likelihood ratio test: $p < 0.001$) (covariates: child's sex, physical exercise, maternal age and education; plus, BMI z-score at age 7 or, in the reverse direction, the subscale score).

In paper II, in cross-lagged analyses, eating large amounts of food at 4 years of age was unidirectional associated with higher Restriction three years later (β̂standardized= -0.047; 95%CI= -0.019, -0.075). Apart from this result, all associations had a bidirectional effect of similar magnitude; eating large amounts of food, eating very slowly and food refusal at age 4 influenced parents to use feeding practices, such as Perceived Monitoring and Pressure to eat at 7 years old, but these practices also prospectively influenced the development of these eating behaviours (e.g. β̂standardized=0.033; 95%CI=0.022, 0.064 for food refusal at age 4 and Pressure to eat at age 7 and β̂standardized=0.060; 95%CI=0.034, 0.086, in the reverse direction) (covariates: child sex, and BMI at 4 years of age and maternal education; plus, the pattern score or the eating behaviour at 4, according to the direction analysed).

In paper III, it was observed that mothers whose children have overweight/obesity frequently failed to identify this (83.8% at 4 and 70.3% at 7 years). After adjustment for maternal education, child's sex and BMI, perceived underweight was associated with practices promoting food intake, such as higher pressure to eat at 4 and 7 years of age (β̂=0.234, 95%CI: 0.243, 0.486 and β̂=0.329, 95%CI: 0.199, 0.459, respectively) and lower restriction at 7 years old (β̂=-0.114, 95%CI: -0.217, -0.010). Perceived overweight was consistently associated with feeding practices at 7 years of age including Covert control (β̂=0.279, 95%CI: 0.170, 0.389), Overt control (β̂=-0.081; 95%CI: -0.157, -0.006), Pressure to eat (β̂=-0.272, 95%CI: -0.401, -0.143) and Monitoring (β̂=-0.102; 95%CI: -0.193, -0.010). Mothers who were concerned about child weight reported higher levels of Restriction (β̂=0.241, 95%CI: 0.178, 0.300 and β̂=0.279, 95%CI: 0.206, 0.339 at 4 and 7 years old, respectively) and Covert control (β̂=0.187, 95%CI: 0.112, 0.261 and β̂=0.185, 95%CI: 0.113, 0.257, respectively). Maternal desire for a heavier child was associated with higher Pressure to eat, while the desire for a thinner child was related to lower Pressure and Monitoring (β̂=-0.320, 95%CI: -0.465, -0.174 at 4 and β̂=-0.142,95%CI: -0.269, -0.015 at 7 years).

Conclusions

Children with a higher BMI in middle childhood are at increased risk of developing an avid appetite over time; the strongest observed relationships were from BMI at 7 years to appetitive behaviours at 10 years, rather than the reverse. Parental feeding practices and children's eating behaviours have a bidirectional relationship, which indicates that parents and children reciprocally influence each other's behaviour. In addition, parents are influenced by their perceptions and concerns with children's weight in the feeding practices that they use. These results highlight the complexity of parents and children dynamics in relation to food.

The current results may be useful in future research and may serve to build the evidence-base for targeted intervention strategies that can guide parents to feed their children in a way that optimizes child's health.

INTRODUCTION

1. Obesity as a Public Health challenge

There is an overall agreement in the scientific community that obesity is one of the major public health challenges of this century. The World Health Organization defines obesity as excessive fat accumulation that might impair health (1). The prevalence of this disease has reached in the last decades epidemic proportions in many populations (2). According to the most recent study providing trends in Body Mass Index (BMI) for all countries of the world, the number of adults with obesity increased from 100 million in 1975 to 671 million in 2016, and 1.30 billion adults were in the overweight range (2). The prevalence of paediatric obesity also raised dramatically from 4% to 18% in these years (2). Data from Portugal, collected in 2015-2016, shows that almost 60% of adults and 25% of children had obesity or pre-obesity (3). These numbers are alarming since obesity significantly increases the risk for developing several diseases, such as type 2 diabetes (4), cardiovascular diseases (5), several types of cancers (6), a range of musculoskeletal disorders (7) and poor mental health (8,9), contributing to a decline in both quality of life and life expectancy (10,11). It has established that 4 million deaths worldwide can be attributed to overweight and obesity (12). The prevalence of paediatric obesity is particularly problematic since it is strongly associated with adult obesity (13,14). There is evidence that it can track into adulthood, with important health consequences; overweight children are more likely to have diabetes and coronary heart disease in adulthood (15).

2. The Behavioural Susceptibility Theory

The upward shift in population weight is widely believed to have been caused by changes in lifestyles and the food supply, creating what is frequently called the 'obesogenic' environment (16). Developments in food production, processing, store and preparation have resulted in an increased supply of cheap, palatable and energy-dense foods (17). Portion sizes of foods have sharply enlarged (18) and food marketing becomes more persuasive and pervasive (18). At the same time, it was observed an increase in sedentary behaviours because of technological advances that make it unnecessary to be

physically active in daily life. The computer-based work dominated most occupations and the leisure-time entertainment becomes dependent on information technology leading to reduced physical activity (19,20). The increase in food consumption parallel with a decrease in energy expenditure generates a positive energy imbalance (more energy is consumed than is expended), and, consequently, weight gain (21).

Notwithstanding the broad pattern of population-level weight gain, individual variation in weight remains high. Even within a family, there can be remarkable differences in weight (22). This suggests that individuals have different susceptibility to the 'obesogenic' environment and the interaction between genes and environmental factors are probably the key factor behind these differences. In fact, the development of obesity has a strong genetic component. The heritability (proportion of inter-individual variation attributable to genetic factors) of BMI has been estimated to be 40–70% (23). Gene-wide association studies (GWAS), in which genetic variants across the genome of many individuals are tested to establish whether any genetic variant is associated with a trait, have identified over 940 independent single nucleotide variants associated with BMI, explaining 6.0% of its variance (24). In face of the current obesity rates, the increasingly 'obesogenic' environment might amplify genetic risk for obesity.

The Behavioural Susceptibility Theory put forward a hypothesis to explain how the interaction between genetic risk and environmental exposures results in weight gain, proposing that genes influence weight through appetitive mechanisms (25). This means inherited differences in appetite can determine how responsive each of us is to the opportunities to eat (26); therefore, individuals who are genetically predisposed to be more responsive to foods are more likely to overeat when exposed to the many opportunities offered by the current food environment (27). This theory can help to explain the genetic-environmental interplay, advocating that obesity arises from a combination of genetic susceptibility to overeating, and exposure to an 'obesogenic' environment (Figure 1).

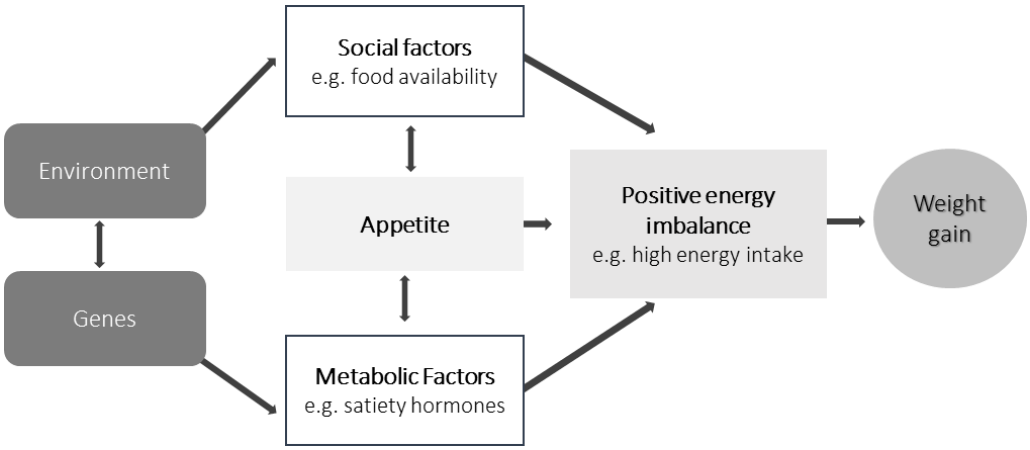

FIGURE 1 How appetite mediates the interaction between genetic susceptibility to obesity and environmental exposures

[Adapted from Llewellyn & Fildes, 2017](27)

3. APPETITE

3.1 APPETITE REGULATION MECHANISMS

Appetite can be defined as a set of processes that influence energy intake (food consumption) and associated motivational drives such as hunger. It can be regarded as a system that reflects a complex interaction of biological, psychological and environmental processes in the overall expression of food intake (28,29).

Homeostatic and hedonic mechanisms influence the regulation of appetite (30). Homeostatic mechanisms are involved in regulating energy balance, comprising both excitatory and inhibitory signals that stimulate and suppress appetite and food intake. It incorporates tonic (energy-storage) and episodic (meal-consumption) control mechanisms. Tonic effects are those with a continuing and stable influence over appetite without significant fluctuations between or within-day (28). Leptin and insulin levels, as well as energy expenditure of metabolically active tissue, are considered the basis of the tonic control mechanism. Episodic influences respond acutely to the presence (or absence) of nutrients in the gastrointestinal tract, varying according to the consumption of food across the day. The satiety peptides (cholecystokinin (CCK), glucagon-like peptide-1 (GLP-1), and peptide tyrosine tyrosine (PYY)) and ghrelin are thought to influence the episodic control mechanisms (28,31). Hedonic mechanisms are

those related to the feeling of reward and pleasure associated with food intake (i.e. liking and wanting) (30,32). Hedonic pathways are activated by highly palatable foods and maintain a drive to eat, stimulating overeating, based on sensory pleasure and reward rather than biological need (33). Despite this distinction, homeostatic interact with hedonic mechanisms and both are likely activated during all feeding situations (34). Recent data suggest that circuits controlling these mechanisms are not completely dissociable (34,35).

The homeostatic control of appetite is often conceptualized through a series of physiological processes that initiate and bring the meal to an end (i.e. satiation), and those which suppress inter-meal hunger (i.e. satiety) (36). The satiety cascaded provides a framework to assess the mechanisms that influence satiation and satiety, identifying different psychological and physiological processes in the control of eating (37). The model also shows how the hedonic and homeostatic processes interact in the overall control of eating (**Figure 2**).

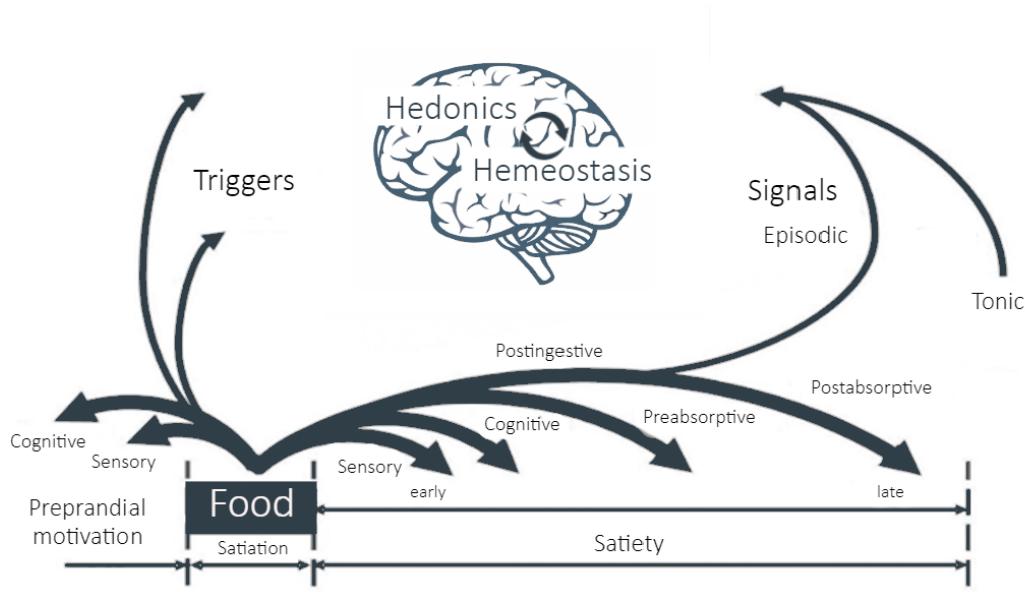

FIGURE 2 Satiety cascade

[Adapted From Blundell, 2018](28)

3.2 APPETITE AND WEIGHT

The association between appetite and weight has been studied for more than half a century (38). Over the years, researchers have identified a cluster of appetitive behaviours associated with weight gain and obesity. During the 60s, Stanley Schachter

with a series of laboratory-based experiments concluded that adults with obesity ate significantly more highly palatable foods than adults with a healthy weight (39). He also observed that individuals with obesity showed a different compensatory down-regulation of food intake after a high-calorie snack when compared to individuals with normal weight (39). Based on these findings, Schachter developed the 'externality theory'. This theory states that individuals with obesity are more responsive to food cues (sight, smell and taste) and less sensitive to internal hunger and satiety signals than their lean peers (39,40). At this time, psychosomatic theories of obesity, relating emotions and eating behaviours, were also formulated aiming to explain the differences in appetite between individuals with obesity and normal weight (41). These theories are focused on the psychological or emotional drivers of eating, such as anger, fear or anxiety, proposing that individuals with obesity overeat to reduce emotional discomfort (42,43). Although all individuals can overeat in response to 'emotional tension' and 'uncomfortable sensations and feelings', individuals with obesity might be more prone to do it (41).

Based on this early research, three key features of appetite were identified - food responsiveness, satiety sensitivity and emotional eating. The Dutch Eating Behaviour Questionnaire (DEBQ) (assesses restraint, emotional and external eating) (44) and the Three-Factor Eating Questionnaire (TFEQ) (assesses restraint, disinhibition and hunger) were the first psychometric questionnaires to be developed to measure different dimensions of appetite (45). These questionnaires have been widely used, and since then evidence suggests that individuals with overweight show higher levels of disinhibition (reflects a tendency towards overeating and eating opportunistically) and hunger (the extent to which hunger feelings are perceived and the extent to which such feelings then evoke food intake) and lower levels of restraint (refers to an individual's concern over weight control and strategies which are adopted to maintain body weight and restrict eating) (46,47). Emotional eating (tendency to overeat in response to negative emotions) and external eating (tendency to overeat in response to tempting food cues) have been also associated with weight gain (48).

Alongside with behavioural measures, the research of biomarkers related to appetite control has major importance. Several peptides and hormones involved in tonic and episodic control mechanisms are associated with weight. Studies evaluating the gut and

adiposity tissue hormones suggest that obesity is associated with a diminished postprandial response of satiety factors such as GLP-1, PYY, CCK and reduced postprandial suppression of orexigenic ghrelin, and some type of central leptin resistance (49).

3.2.1 APPETITE AND WEIGHT IN CHILDHOOD

The first studies evaluating the association between appetite and weight in childhood were focused on underweight and insufficient weight gain (50) because childhood obesity had low prevalence until the 21st century (16). However, the increasing rates of paediatric obesity shifted attention to the role of appetite and eating behaviours on excessive weight.

The Children Eating Behaviour Questionnaire (CEBQ), developed by Professor Jane Wardle, was the first comprehensive psychometric measure to evaluate appetite in children from 2 to 7 years of age (51). The CEBQ measures eight different dimensions of appetitive behaviours, which are frequently grouped into 'food approach' and 'food avoidance' behaviours. The 'food approach' behaviours are those related to a higher interest in food, higher sensitivity to external food cues, and overeating in response to negative emotional states. The 'food avoidance' behaviours are those associated with higher responsiveness to internal satiety cues, eating slowly during meals, a lack of interest in food and unwillingness to try new food and under-eating in response to negative emotions (51). Most recently, this questionnaire was adapted to be used in infants (52) and toddlers (53). Apart from psychometric measures, appetitive behaviours in children can be also assessed using experimental designs and direct observations in laboratory settings. Various methods have been applied for the assessment of appetitive behaviours and to explore the associations between these and weight, as illustrated in TABLE 1.

TABLE 1 Different methods and measures to assess appetitive behaviours and the association with weight

Appetitive behaviour	Method(s) of assessment	Description	Association with weight
Direct observations			
Eating in the absence of hunger (EAH)	Direct observation in a laboratory setting (54).	Eating when satiated in response to the presence of palatable snack food (55).	Higher in children with overweight (56–59) and predicted BMI in longitudinal studies (54,60–62).
Eating rate	Direct observation of (usually) videotapes (63).	Total energy or mouthfuls of food consumed within a given time interval (64).	Eating rate was positively associated with BMI (children with excessive weight eat faster) (63,65–67).
Experimental measures			
Compensation of energy intake	Compensation trials (68)	Adjustments in intake in response to changes in the caloric content of a preload (fixed amount of food or nutrient) after a predetermined time delay (69).	Children with overweight under-compensate (eat more after a preload meal) (58,68,70,71). Some studies have found no association with weight (72,73).
Psychometric measures			
Enjoyment of food	CEBQ (51)	General interest in food and the amount of pleasure experienced when eating (27).	Consistently associated with a higher weight (74–79).
Desire to drink	CEBQ (51)	Desire to drink liquids, particularly sugar-sweetened beverages (27).	Some studies reported a positive association with weight (74,79), but others found no association (76–78).

Food responsiveness	CEBQ (51)	Eating in response to food cues (such as the sight or smell of food) (27).	Consistently associated with a higher weight (25,74–79) and related to BMI in longitudinal studies (80,81).
Satiety responsiveness	CEBQ (51)	The ability to recognize and adjust eating in response to internal feelings of satiety or fullness (27).	Consistently associated with lower weight (25,74–79) and related to BMI in longitudinal studies (80–82).
Emotional overeating	CEBQ (51)	Undereating in response to negative emotional states (27).	Most studies have reported a positive association with weight (74,75,77,79), but others found no association (76).
Slowness in eating	CEBQ (51)	Eating slowly during a meal (27).	Consistently associated with a lower weight (74,76,77,79).
Emotional undereating	CEBQ (51)	Overeating in response to negative emotional states (27).	Some studies showed a negative association with weight (75,78), but others found no association (76,77,79).
Food fussiness	CEBQ (51)	Being highly selective of foods (27).	Mostly associated with lower weight (74,75,77,78), but there are some inconsistencies (76,79). There is some evidence from longitudinal data (83).

CEBQ: Children Eating Behaviour Questionnaire

A large body of cross-sectional research supports that individual differences in appetite are associated with weight in childhood (74–79). Children with a more avid appetite have a higher probability of accumulating body fat and consequently having excessive weight and obesity; while those with a poor appetite are more likely to have less body fat and having underweight. However, despite extensive literature in this area,

most studies did not examine appetitive behaviours as predictors of changes in children's weight status over time neither the possibility of an influence of weight on appetite, thus the cause-effect relationship still needs to be clarified. Recently, a few studies have used cross-lagged models to identify the direction of associations between appetitive behaviours and weight (84–86). The major goal of this analytic approach is to examine the causal influences between variables (87). The models are considered 'crossed' because they estimate relationships from one variable to another and vice versa. They are considered 'lagged' because they estimate relationships between variables across different time points (87). From early to middle-childhood, in two studies BMI predicted the four appetitive behaviours analysed (Food Responsiveness, Enjoyment of Food, Emotional Overeating and Satiety Responsiveness) rather than the reverse (84,85), suggesting that weight might influence the development of appetite across time. In contrast, in infancy (from 3 to 15 months) associations from appetite to weight were the strongest (88). Enjoyment of food, Food responsiveness, Slowness in eating, Satiety Responsiveness, and general appetite rating at 3 months of age were prospectively related to subsequent weight independent of early weight (88). Based on these studies, age might be a key factor influencing the strength and direction of associations. To elucidate this, it is important to perform further longitudinal studies in different population samples with multiple assessments of appetitive behaviours (including more domains) and weight across time.

4. FACTORS INFLUENCING APPETITE

4.1 GENETICS

Evidence from twin and molecular genetic studies highlights that genetic inheritance may have an important role in the development of appetite. Twin studies, which compare monozygotic (identical) twins with dizygotic (non-identical) twins, allow to investigate and quantify the contribution of genetic and environmental influences on a trait. Using this methodology, heritability estimates for appetitive behaviours range from 0 to 75%, with most of them in the upper-moderate range (heritability >50%) (63,71,89–92).

GWAS have identified several genes associated with an increased risk of obesity (93). To the date, the fat mass and obesity-associated gene (FTO) explained the largest amount of variation in BMI (94). Several studies have linked FTO and other obesity-related genetic variants and phenotypes associated with appetite among children and adults, including food responsiveness (95), satiety responsiveness (96,97), emotional eating (98–100), disinhibition and susceptibility to hunger (99–101), and deregulated neurobiological mediators of appetite (102). These results support the hypothesis that genetic predisposition to obesity may act via mechanisms that regulate appetite.

4.2 Environmental factors

4.2.1 Early feeding environment

Despite the strong heritably of appetite, environmental factors play a pivotal role. The literature shows that the shaping of appetite and eating behaviours start to occur prenatally (103). The foetus has his first taste experiences with the amniotic fluid, which is flavoured by the mother's diet. There is evidence that foetal flavour exposure increases acceptance of similarly flavoured foods when re-exposed during infancy and potentially childhood (104). In milk feeding the breast milk flavour composition may vary with maternal diet, while infant formula has the same taste over time (105). The sensory experience of human breastmilk has been suggested to influence food acceptance through flavour learning (106). The type of formula may also influence the acceptance of tastes too; infants fed with hydrolysed casein formulas, which have pronounced bitter, sour, and savoury tastes, seem to accept better foods with these flavours later (107,108). The way each infant is fed, whether directly from the breast or bottle-fed, might be a factor to consider as well. Direct breastfeeding during early infancy was related to greater appetite regulation later in childhood (109,110). In bottle-feeding mothers/caregivers have control about the volume of milk offered and the quantity consumed by the infant, which might encourage the caregiver to feed an infant independent of internal hunger and satiety cues (111). Additionally, shorter breastfeeding duration was linked to poorer satiety response and higher eating in the absence of hunger (112).

Complementary feeding is a key period for learning food preferences and appetite control, in which infants discover the sensory and nutritional properties of foods (113).

Infants are born with taste predispositions that include rejection of novel foods (food neophobia) and bitter/sour tastes and preference for sweet tastes (114). Repeated exposure to a wide variety of foods and textures are effective strategies to increase food and flavour acceptance during complementary feeding (115). Timing of the introduction of solid foods has been also related to later food acceptance (116,117).

4.2.2 PARENTAL FEEDING PRACTICES

Parents construct their children's physical and social environment, for example, by buying foods, setting rules about timing, frequency, structure and by the interaction they have with their children during meals (118). The strategies used by parents aiming to control or modify what, when and how much the child eats (i.e. parental feeding practices) have been shown to affect eating behaviours (118). Responsive feeding that recognizes and responds appropriately to child cues of hunger and satiety are believed to hold importance in child's development of appetite self-regulation (111). On the other hand, feeding for other reasons than hunger and feeding beyond satiety are hypothesized to impair child-satiety response (111).

Recently, Vaughn and colleagues mapped and categorized the food parenting practices documented in the literature into three higher-order constructs – coercive control, structure, and autonomy support – with multiple specific practices within each construct (119). Coercive control refers to a specific control that reflects attempts to dominate, pressure, or impose the parents' will upon the child, including practices such as restricting the child's access to food, pressuring the child to eat and using food as a reward or to control negative emotions (119). These feeding practices are the most studied and appear to have detrimental effects on children's eating behaviours (119). Pressure to eat was associated with food avoidance behaviours (78,120,121), while restrictive feeding practices were related to an increased tendency to overeat and higher food responsiveness (78,120,122) and enjoyment of food (123). Instrumental feeding (using food to reward children's behaviour) has been associated with higher emotional overeating, food responsiveness, and eating in the absence of hunger (124,125).

Structure is based on parents' organization of the child's food environment to help the child learn and maintain certain dietary behaviours, including parents' consistent

enforcement of rules and boundaries about eating (119). Structure includes practices such as rules and limits, limited or guided choices, monitoring, role modelling, and food availability and accessibility (119). The current evidence has been shown that these practices might have positive effects on child diet-related outcomes. Structured meal setting and family meal setting were related to heightened levels of self-regulation in eating (126). Monitoring (the extent to which parents track what and how much the child is eating) (127) was negatively associated with the tendency to overeat and other food approach behaviours (78,123,128). Modelling (measured as parental intake of a target food item) was associated with both healthy and unhealthy food consumption (129); similar results were observed for food availability and accessibility (129).

Autonomy support concerns offering children choices and allowing for age-appropriate independent exploration, providing support to nurture the child's capacity to self-regulate when the parent is not around (119). Autonomy support includes parental strategies such as using the logic to persuade children to change their eating behaviour (reasoning); using positive reinforcement through verbal feedback (praise), positively, gently, and supportively inspire their children to adopt healthy eating habits (encouragement); and involving a child in the planning and preparation of meals (119). These practices have been associated with healthier food choices (130–132), greater enjoyment of food and lower food fussiness (133).

Many instruments have been developed for assessing the dimensions of parental feeding practices (134). The most widely applied tool is the Child Feeding Questionnaire (CFQ) (127), which has been demonstrated to have good internal consistency, validity, and reliability (135). This questionnaire comprises seven subscales. Four subscales measuring parental perceptions and concerns about body weight, both their child's and their own that may affect parental control of children's eating: Perceived responsibility (assessing parents' perceptions of their responsibility for child feeding), Perceived parent weight, Perceived child weight, and Concern about child weight. Three subscales measuring parental feeding practices and attitudes: Restriction (the extent to which parents restrict their child's access to food); Pressure to eat (tendency to pressure the children to eat more food); and Monitoring (the extent to which parents supervise their child's eating) (127). Other popular and validated instruments include The Parental

Feeding Style Questionnaire (PFSQ) (136), the Food-Related Parenting Practices Questionnaire (137), the Comprehensive Feeding Practices Questionnaire (CFPQ) (138) and the Scale of Overt and Covert Control (139). The latter was conceptualized to distinguish overt and covert restrictive feeding practices. Overt control refers to explicit control over food consumption, such as being firm about what a child should eat, while covert control refers to controlling food intake in a way that cannot be detected by a child, such as avoiding keeping snack foods in the house (139).

There is a considerable body of research supporting the view that the feeding practices used by parents can shape children's eating behaviours. However, studies have mostly analysed the unidirectional relationships between parental practices and children's behaviours, which are likely bidirectional, since parents adapt their feeding practices in response to their child's characteristics (122,140–144). Thus, it is plausible that parents and children mutually influence each other's behaviour. A few recent studies have analysed this hypothesis, testing whether parental feeding practices are a predictor or a consequence of children's eating behaviours through cross-lagged analysis (124,145–147). However, it is still difficult to identify the direction of many associations. It was found both unidirectional (parents influencing children's behaviours or the reverse) and bidirectional relationships, depending on the feeding practice and eating behaviour analysed and children's age (84,145,147). Further investigation is needed to clarify these complex relationships; studies with larger samples and longer follow-up periods are lacking, and the bidirectional effect of several feeding practices, some of them highly correlated with children's eating behaviours, was not evaluated yet.

4.2.2.1 FACTORS INFLUENCING PARENTAL FEEDING PRACTICES

The feeding practices used by parents result from an interaction between parent's and child's characteristics. Parents seem to adapt their feeding practices depending on their child's temperament (148), weight (144,145,149) and appetitive behaviours (122,140–143), as well as their perceptions and beliefs about these characteristics (143,150–156). For instance, when parents are concerned about the child weight status or consider that the child is eating too much, they tend to use more restrictive feeding practices to control food consumption (142,157,158). On the other hand, when they are

worried about underweight or they perceived that the child is not eating enough, parents are likely to use strategies to promote food intake (120,151,158).

Demographic differences in feeding practices are also evident. Socioeconomic characteristic, such as family income and education, and cultural background are important aspects to consider (159–162). Personality factors and psychological health have also been shown to influence parental feeding practices (159,161–163).

There is a large body of research examining the determinants of parental feeding practices (162). However, many of the studies focused only on simple correlations not adjusting for potential confounders, and most analyses are limited to a one-time point (162). Parents and children's characteristics can change over the years. As children grow, their eating behaviours, food consumption and weight status change, which can influence parents' cognitions, such as their perceptions and concerns about children's weight, adapting their feeding practices to achieve different goals. Therefore, it is important to elucidate how different factors can influence parental feeding practices across time.

5. A MODEL OF BIOLOGICAL AND PSYCHOSOCIAL PROCESSES IN THE DEVELOPMENT OF APPETITIVE BEHAVIOURS AND WEIGHT IN CHILDREN

Russel and Russell have developed a model to conceptualize the biological and psychosocial factors that influence children's appetitive behaviours and weight (164) (Figure 3). The model focuses on characteristics, behaviours, and cognitions of parents and children, as well as their interactions and influences over time (165). Biological factors are related to genetic predispositions and other biological foundations of the child (164). The psychosocial influences concern parental factors, such as parental feeding practices and other elements of the family and home environment (164). Biological factors are assumed to influence the development of appetitive behaviours and other children's characteristics. These characteristics can influence parental cognitions (such as beliefs about children and diet), expectations (e.g., about children and their behaviour), and interpretations (e.g., about causes of weight gain in children), which in turn can affect parental behaviour such as their feeding practices (165).

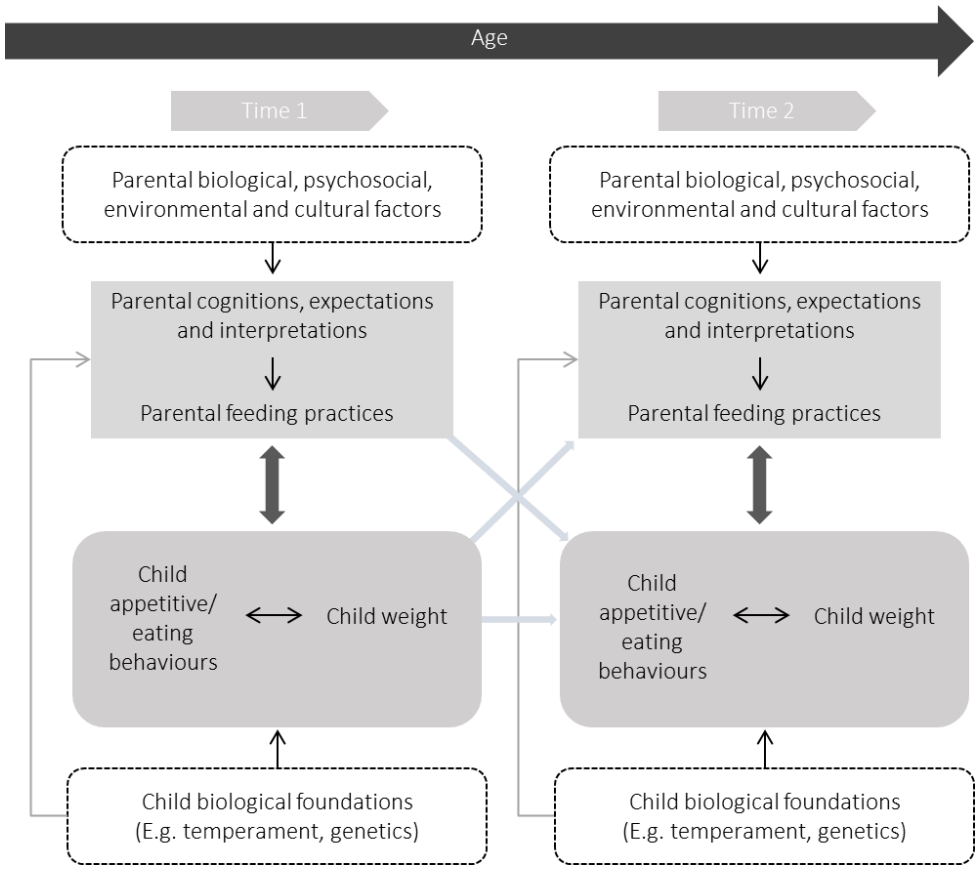

FIGURE 3 A model of biological and psychosocial processes in the early development of children eating behaviours and weight

[Adapted from Russell and Russell, 2018 and Russell and Russell, 2019] (164,165)

Based on this model, this thesis will focus on the complex relationships between weight, appetitive behaviours, and parental feeding practices in childhood, aiming to understand how they reciprocal influence each other over time (Figure 4). As highlighted previously, individuals have different appetitive profiles, those with a more avid appetite or lower sensitivity to satiety are more likely to overeat in response to the food environment, which might lead to weight gain (25). Individuals differences in appetitive behaviours have a strong genetic basis and seem to arise since early life (89,90). However, the role of the environment cannot be discarded. Parents have direct control over child's diet by managing the quantity and quality of their food intake and through the use of certain feeding practices; therefore, they might have the potential to promote good child eating self-regulation or to foster the development of obesogenic eating behaviours (105). The parent and child relationship is likely reciprocal, since child's characteristics, such as their weight and eating behaviours, can influence parents' choices.

The purpose of this thesis was to address some gaps in the existing literature. Most previous studies have a cross-sectional design or only have analysed the unidirectional relationship between variables. Using data from a large birth cohort with repeated measures of weight, appetite behaviours and parental feeding practices, we were able to examine bidirectionality. As parental feeding practices are complex and influenced by a wide range of factors, it was also explored how parental perceptions and concerns affect their feeding behaviours across time.

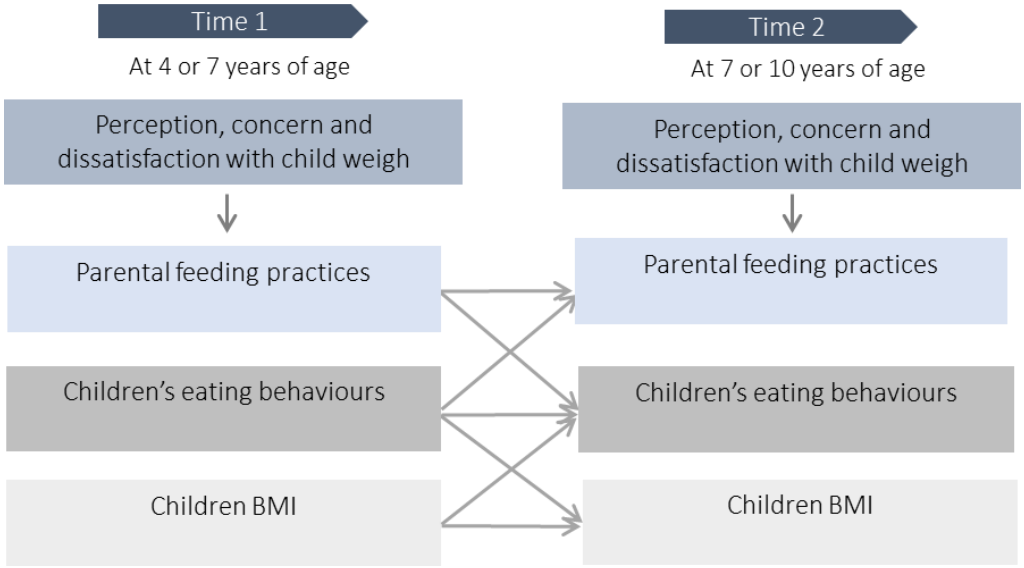

FIGURE 4 A conceptual framework for the associations between children weight and appetitive behaviours and parental feeding practices

OBJECTIVES

This thesis aims to understand the association between weight and appetite behaviours during childhood and the role of parental feeding practices in the development of these behaviours, as well as how parents' respond to their child's characteristics in the context of feeding. To evaluate this, it was used data from a prospective population-based birth cohort (Generation XXI). The following specific objectives were defined, resulting in three papers:

- To analyze the bidirectional relationships between appetitive behaviours and body mass index from 7 to 10 years of age (paper I).
- To examine the bidirectional associations between parental feeding practices and eating behaviours from 4 to 7 years of age (paper II).
- To study how maternal perception, concern and dissatisfaction with child weight are associated with feeding practices at 4 years of age and three years later (paper III).

SCIENTIFIC PAPERS

PAPER I

BIDIRECTIONAL RELATIONSHIPS BETWEEN APPETITIVE BEHAVIOURS AND BODY MASS INDEX IN CHILDHOOD: A CROSS-LAGGED ANALYSIS IN THE GENERATION XXI BIRTH COHORT [EUR J NUTR 2020]

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ORIGINAL CONTRIBUTION

Bidirectional relationships between appetitive behaviours and body mass index in childhood: a cross-lagged analysis in the Generation XXI birth cohort

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Abstract

Purpose Appetitive behaviours have been associated with body mass index (BMI). However, existing data were largely derived from cross-sectional studies and cannot provide insight into the direction of associations. We aimed to explore the bidirectionality of these associations in school-age children.

Methods Participants are from the Generation XXI birth cohort, assessed at both 7 and 10 years of age ($n = 4264$; twins excluded). The Children's Eating Behaviour Questionnaire (CEBQ) was used to measure appetitive behaviours (8 subscales). Anthropometrics were measured and WHO BMI z-score was calculated. Cross-lagged analyses were performed to compare the magnitude and direction of the associations (behaviours at 7 years to BMI z-score at 10 years and the reverse) (covariates: child's sex, physical exercise, maternal age and education; plus BMI z-score at age 7 or, in the reverse direction, the subscale score).

Results In cross-lagged analyses, appetitive behaviours at 10 years of age (apart from emotional undereating) were shown to be reactive to the child BMI z-score at 7 years of age. Only slowness in eating was significantly related to subsequent BMI. However, the strongest association was from the child BMI z-score to the behaviour ($\beta_{\text{standardized}} = -0.028$ compared with $\beta_{\text{standardized}} = -0.103$, likelihood ratio test $p < 0.001$).

Conclusions BMI at age 7 was related to appetitive behaviours at 10 years of age, rather than the reverse. This suggests that children with a higher BMI in middle childhood are at increased risk of developing an avid appetite over time.

Keywords Eating behaviours · Appetite · BMI · Child · Longitudinal · Cross-lagged

Background

Genetic predispositions explain a large proportion of the variation in appetitive behaviours during childhood [1–3]. Previous studies have showed that appetitive behaviours can play an important role in weight gain during childhood [4–9]. Children with higher weight are more sensitive to external food cues, eat faster during meals, have a lower responsiveness to internal satiety signals and overeat in response to emotional stimuli [4, 10–15]. Behavioural susceptibility theory proposes that individual differences in appetite have a strong genetic basis and these differences causally influence body weight [10]. However, the literature supporting this theory remains limited. Studies are largely cross-sectional and rely on samples of children from broad age-ranges, rather than assessing the same children repeatedly [4, 7, 10]. This makes it difficult to explore differences in associations by age and raises the possibility of reverse causality—making it impossible to determine whether variation in appetite is a determinant or consequence of adiposity.

The few prospective studies conducted to date report mixed findings. Food fussiness at age 4 predicted a lower BMI 2 years later [16], while higher food responsiveness (representing a high interest in eating) and poorer satiety responsiveness (representing a low degree of self-regulation

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of the amount of food consumed) were positively associated with weight in infancy, from 3 to 24 months [17], and in early childhood, from 2 to 4 years of age [18]. A Norwegian cohort study analysed the relationships between appetite and weight in different directions and reported that higher food responsiveness at 6 years of age predicted more rapid weight gain to age 8. However, a reversed effect was also observed, BMI at age 4 predicted higher levels of food responsiveness and lower satiety responsiveness at age 6 [19]. An additional follow-up to age 10, supports that body composition (fat mass and muscle mass) also predicts appetitive behaviours from 6 to 8 and 8 to 10 years of age [20].

Determining the direction and magnitude of the associations between appetitive behaviours and adiposity requires large cohort studies with repeated measurements of BMI and child eating behaviours. The Gemini birth cohort was the first to examine the bidirectional relationship between appetite and weight from birth, and showed the pathway from appetite at 3 months to weight at 9 months was stronger than the pathway from weight at age 9 months to appetite at 15 months, supporting the hypothesis that appetite prospectively influences weight gain [6]. However, this analysis focused on a short time period in very early childhood, while it might be that the relationships between appetite and weight may differ in older children. Most recently, another study from the Generation R cohort in the Netherlands explored bidirectional relationships between BMI and appetitive traits from ages 4 to 10. Higher BMI at 4 years predicted higher food responsiveness and enjoyment of food and less satiety responsiveness at 10 years, but no associations were found in the opposite direction. Bi-directional associations were reported for emotional overeating and BMI [21], suggesting that increased adiposity in early childhood might have an effect on upregulating appetite.

The present study aims to examine the direction of the associations between appetitive behaviours and BMI across childhood (from ages 7 to 10), contributing to a better understanding of mechanisms influencing weight gain.

Methods

Study population

This study includes participants from the population-based birth cohort Generation XXI, described elsewhere [22]. A total of 8647 liveborn infants were enrolled between April 2005 and August 2006 in all level III public maternity units from the metropolitan area of Porto (northern Portugal). All families were invited to attend evaluations when children were aged 4, 7 and 10-years-old (86%, 80%, and 74% participation proportion, respectively). The present study included all children who attended both evaluations ($n = 6115$). Twins and children with missing information on variables of interest (CEBQ, BMI and potential confounders) were excluded ($n = 1851$) (Flowchart of participant's selection-Fig. 1), resulting in a total of 4264 participants. Comparing some maternal and child characteristics from the study sample with the remaining cohort, the mothers were slightly older (mean = 30.0, SD = 5.1 vs mean = 29.9, SD = 5.2 years) and more educated (mean = 11.4, SD = 4.3 vs mean = 11.2, SD = 4.3 years).

This study was conducted according to the principles of the Declaration of Helsinki and all procedures were approved by the Ethical Committee of São João Hospital/University of Porto Medical School and by the Portuguese Authority of Data Protection. Legal representatives of each participant received an explanation of the purposes and design of the study and gave written informed consent at baseline and at each follow-up assessment.

Data collection

Appetitive behaviours at 7 and 10 years of age were assessed with the Children's Eating Behaviour Questionnaire (CEBQ). The CEBQ is a parent-reported psychometric measure developed and first validated by Wardle et al. [23]. It is a 35-item instrument that measures eight factors (subscales) related to distinct eating behaviours: Food Responsiveness (5 items), Enjoyment of Food (4 items), Emotional Overeating (4 items), Desire to Drink (3 items), Satiety Responsiveness (5 items), Slowness in Eating (4 items), Emotional Undereating (4 items), Food Fussiness (6 items).All items were scored on a 5-point Likert scale as never, rarely, sometimes, often or always. In accordance with the original scale, five of the items were reverse-scored due to opposite phrasing. Data were recovered from questionnaires that were missing $< 50\%$ data of items, by replacement for the average of the remaining questions within each subdomain of the participant (around 3% at 7 and 10 years).

The CEBQ is a widely used tool and has demonstrated good internal consistency, concurrent validity with actual appetitive behaviour, test–retest reliability, and stability over time [4, 7–11, 23–25]. It has been shown to have good psychometric properties in Portuguese 7-years-old children [26]. At both time points, Cronbach's alpha coefficients for each CEBQ subscale were calculated to assess the internal consistency, at 7 years of age ranged from 0.74 to 0.85 and at 10 years ranged from 0.76 to 0.84.

Child anthropometrics were measured at both ages by trained staff and a detailed description of procedures followed is described elsewhere [27]. The child BMI was defined as weight in kg divided by squared height m^2, and age- and sex-specific BMI standard deviation scores (BMI z-scores) were computed according to the World Health

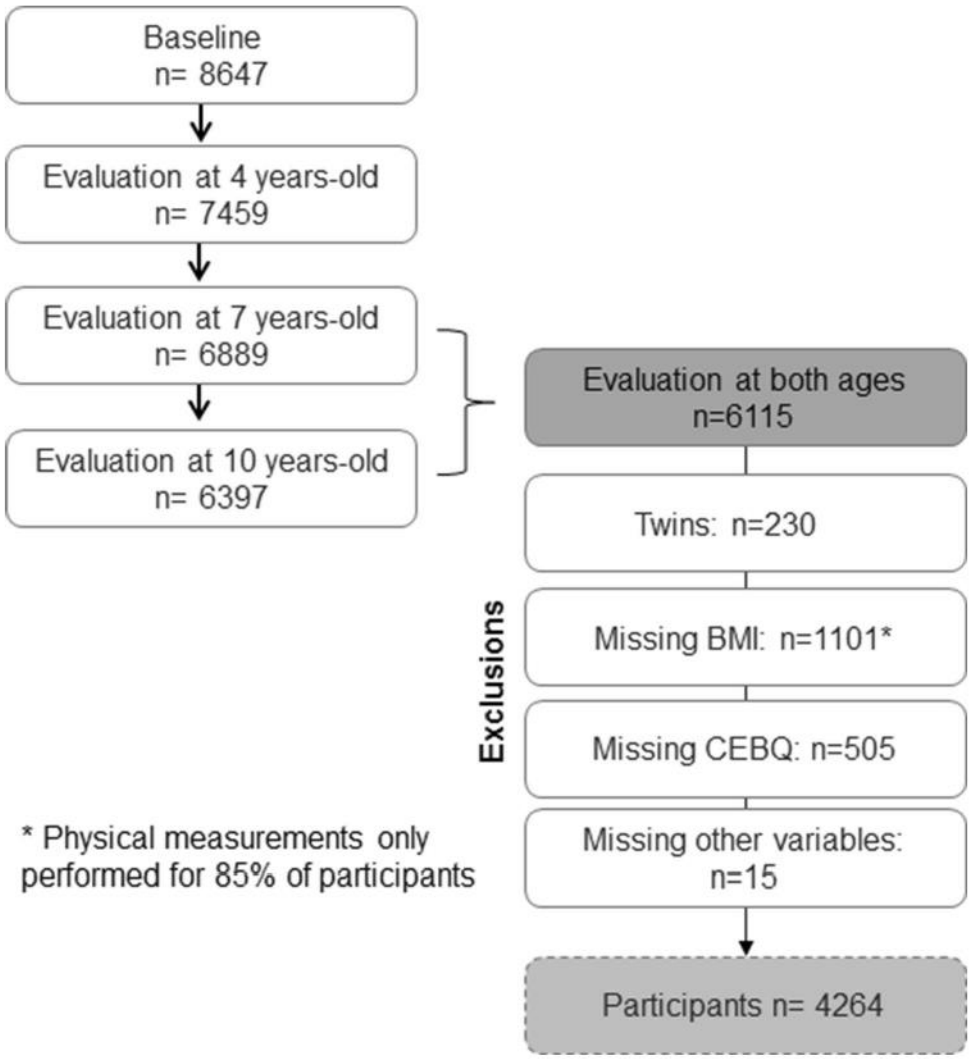

Fig. 1 Flowchart of participant's selection

Organization Growth Reference for school-aged children [28].

Co-variates were chosen based on previous literature and tested in the current sample, namely child's sex, birth weight and regular practice of physical exercise (based on a dichotomous question (no vs. yes) *"Does the child practice any kind of scheduled and regular sport at school or out of school?"*) [26]. Maternal age and educational level were recorded as completed years of ageing and schooling, maternal anthropometric measurements were performed by trained staff and BMI was calculated. Parental feeding practices at 7 years of age were assessed through a questionnaire self-completed by parents or caregivers. The questionnaire used is a combined version of the Child Feeding Questionnaire (CFQ) [29] and the scales of overt and covert control [30]. This version was previously adapted and validated to Portuguese preschool children [31].

Statistical analysis

Cross-lagged analyses were performed (one for each subscale) to compare the magnitude and direction of the associations. This analysis included linear regressions to assess the longitudinal association (tracking) of each variable from 7 to 10 years of age, and the longitudinal association of the cross-lagged paths (eating behaviours at 7 years with BMI *z*-scores at 10 years, and the reverse). Each model comprised cross-sectional correlations between appetitive behaviours and BMI z-score at each time point. A likelihood ratio test was used to compare whether the two cross-lagged standardized regression coefficients of appetitive behaviours with the child's BMI differed statistically from each other, constraining the cross-lagged regression coefficients to be equal (model A) and comparing with the model that was not constrained (model B).

Potential confounding factors were individually assessed in each model and those that did not change the association of interest were removed (such as birth weight and maternal BMI). All associations were adjusted for the child's sex, physical exercise at 7-year-old, maternal age and maternal education. In an additional set of analyses, we also tested a possible interaction of child's sex and parental feeding practices in the associations. Interaction terms (appetitive behaviours * feeding practice or child's sex in appetite—BMI associations; and BMI * feeding practices or child's sex in BMI—appetite associations) were added to adjusted linear regression models. This analysis allowed us to examine if child's sex or parental child-feeding practices modify the associations between appetitive behaviours and BMI and the reverse.

A Comparative Fit Index (CFI) and a Tucker-Lewis Index (TLI) ≥ 0.90, and a Root Mean Square Error of Approximation (RMSEA) close to 0.06 and a standardized root mean square residual (SRMR) close to 0.08 were used as criteria to support the goodness of fit [32–34]. Descriptive statistics were performed in SPSS®software 25.0. and the cross-lagged analyses were conducted using R® 3.0.1 statistical software. Statistical significance and 95% Confidence intervals were described using Bonferroni`s correction. An alpha (α) of 0.006 ($\alpha = 0.05/8$) was used for statistical significance, and 99.4% confidence intervals were estimated.

Results

Characteristics of children and their mothers are presented in Table 1. In our sample, 51.6% were girls. The mean change in BMI from 7 to 10 years-old was 1.8 kg/m^2.

A cross-lagged modelling approach to compare the associations in both directions (from appetitive behaviours to BMI and the reverse) was applied (Fig. 2). All models showed an acceptable fit. This analysis showed that all appetitive behaviours at 10 years of age (apart from emotional undereating) were reactive to children's BMI z-score at 7 years of age. The strongest associations were with food responsiveness ($\beta_{standardized} = 0.198$; 99.4% CI = 0.165, 0.231), enjoyment of food ($\beta_{standardized} = 0.172$; 99.4% CI = 0.138, 0.206) and satiety responsiveness ($\beta_{standardized} = -0.146$; 99.4% CI = − 0.180, − 0.112). Regarding associations between appetitive behaviours at 7 and BMI z-scores at 10 years of age, only slowness in eating was inversely associated with changes in BMI z-scores. However, the strongest direction was from the children's BMI *z*-score to

Table 1 Characteristics of study participants ($n = 4264$)

Maternal characteristics		
Age at baseline (years), mean (SD)	30.0 (5.1)	
Educational level at baseline (years), mean (SD)	11.4 (4.3)	
Child's characteristics		
Sex, *n* (%)		
Girls	2200 (51.6%)	
Boys	2064 (48.4%)	
	Yes	No
Physical exercise at 7 years of age, *n* (%)	3662 (85.9%)	602 (14.1%)
	7 years	10 years
Child's weight status, mean (SD)		
BMI (kg/m^2)	18.8 (3.4)	17.0 (2.4)
BMI *z* score	0.7 (1.2)	0.7 (1.2)
Δ BMI (kg/m^2)[a]	1.8 (1.6)	
Children's appetitive behaviours[b], mean (SD)		
Food responsiveness	2.0 (0.8)	2.2 (0.8)
Enjoyment of food	3.0 (0.8)	3.1 (0.8)
Emotional overeating	1.8 (0.7)	2.0 (0.7)
Desire to drink	2.2 (0.8)	2.1 (0.7)
Satiety responsiveness	2.7 (0.7)	2.7 (0.7)
Slowness in eating	2.9 (0.9)	2.7 (0.9)
Emotional undereating	2.5 (0.8)	2.4 (0.7)
Food fussiness	3.0 (0.8)	3.0 (0.8)

SD standard deviation, *BMI* Body mass index; Δ change

[a]BMI variation from 7 to 10 years old

[b]Possible range 1– 5

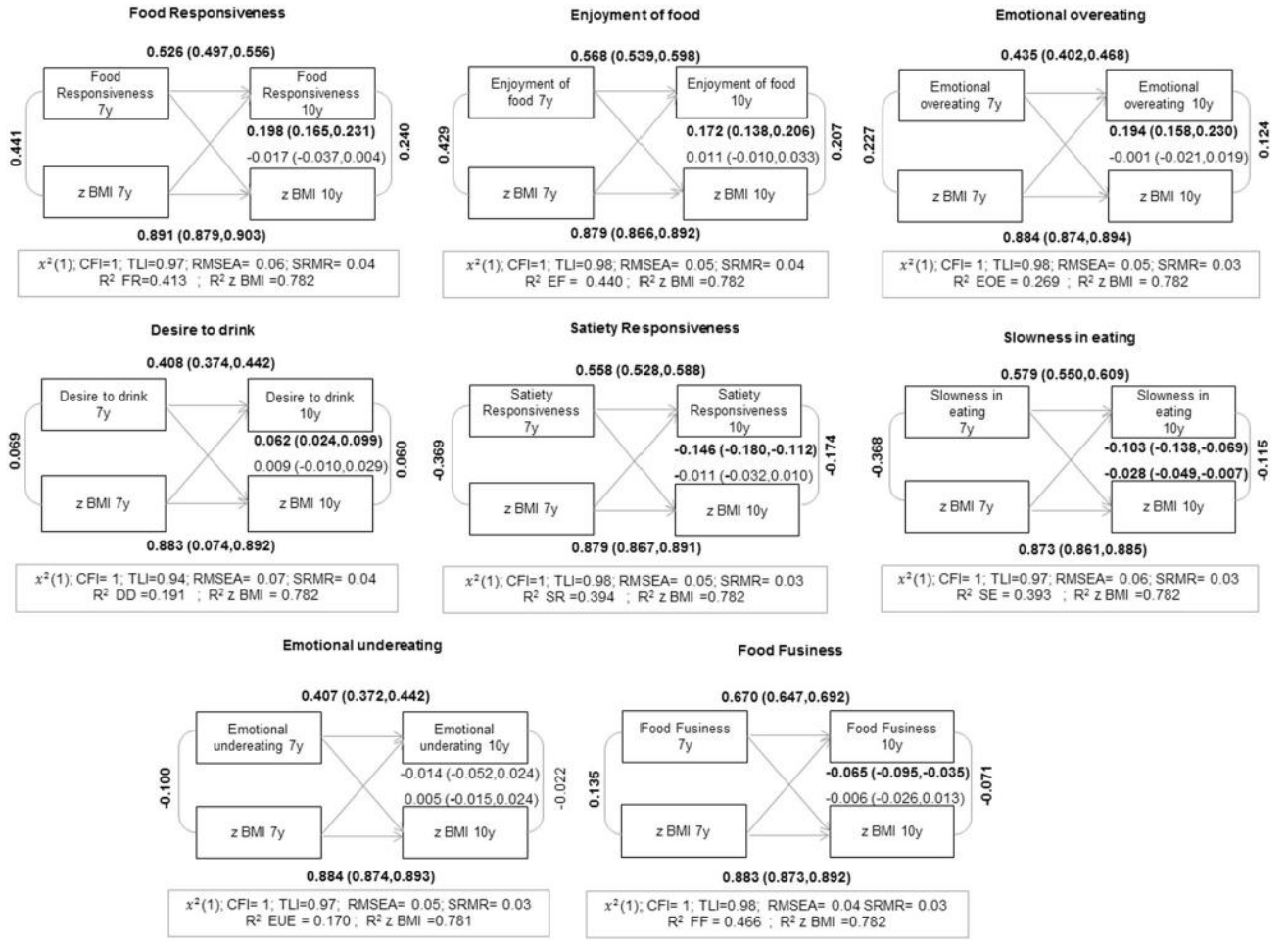

Fig. 2 Cross-lagged models on the associations between children's appetitive behaviours and BMI *z*–scores. For longitudinal associations, values represent standardized $\hat{\beta}$-regression coefficients with corresponding 95% Confidence Interval with Bonferroni's correction. Each model includes cross-sectional correlations at each time point. All associations are adjusted for child's sex, physical exercise, maternal age and maternal education. Significant results ($p < 0.006$) are shown in bold font. R^2 variance explained by the model, *CFI* comparative fit index, *RMSEA* root mean square error of approximation, *SRMR* standardized root mean square residual, *TLI* Tucker–Lewis index

the eating behaviour, as confirmed by the likelihood ratio test ($\beta_{\text{standardized}} = -0.028$; 99.4% CI = $-0.049, -0.007$ compared with $\beta_{\text{standardized}} = -0.103$; 99.4% CI = $-0.138, -0.069$; likelihood ratio test: $p < 0.001$).

Additionally, we tested the effect of child's sex and parental feeding practices (such as pressure to eat and restriction) in the associations between appetitive behaviours and BMI. After testing an interaction effect the estimates did not change, thus results are reported for all children.

Discussion

This study concluded that there is an association between BMI z-score at 7 years of age with appetite behaviours three years later. The cross-lagged analysis conducted suggests BMI prospectively influences children's appetitive behaviours, rather than the reverse. A bidirectional relationship was only found for slowness in eating, although the effect of the child's BMI over the appetitive behaviour was the strongest.

Thus, the appetitive behaviours seem to follow BMI rather than to precede. This is in accordance with the results of the Generation R cohort study that explored these bidirectional relationships from ages 4 to 10. For all four appetitive behaviours examined (food responsiveness, enjoyment of food, satiety responsiveness, and emotional overeating), the pathway from BMI to appetitive behaviours was the strongest; and only emotional overeating was bi-directionally associated with BMI. The standardized effect size of the associations between BMI and eating behaviours was slightly lower but comparable to our results. Moreover, the

authors reported that these associations occur for fat mass and fat-free mass too [21]; results not presented in our study. Regarding emotional overeating, the different results might be explained by the different age of the children, our study included older children and emotional eating is expressed with increasing age [35]. At 7 years of age, children are already at school and have increased autonomy, including in relation to food. Therefore, a higher level of emotional overeating in early ages might predict a higher BMI later on, but in older children, the effect could be smaller. Our findings regarding the effect of weight in appetitive behaviours are also supported by other longitudinal studies, recently published. A study performed in a sample of 807 Norwegian children found higher fat mass predicted greater increases in food responsiveness over time (from ages 6 to 8 and 8 to 10 years) [20]. While another study from the same cohort found a high BMI z-score at 4 years-old was associated with increased food responsiveness and decreased satiety responsiveness at 6 years [19].

The UK-based Gemini cohort study examined bidirectional associations between appetitive behaviours and weight at earlier ages [6]. Findings suggested the pathway from appetitive behaviours (food responsiveness, enjoyment of food, and satiety responsiveness) at 3 months to weight at 9 months was stronger than the pathway from weight at age 9 months to appetitive behaviours at 15 months. However, it is not possible to directly compare the results because these analyses focused on a 6-month time interval in infancy. At 3 months the infants were exclusively milk-fed so appetitive traits are quite different [6, 17]. This study also coincides with the greatest change in rates of weight gain seen in the first 1–2 years of life [36]. It is difficult to find these same associations in older children because of the comparatively smaller changes in weight or weight gain which occur after that period. It is also possible that the relationships between appetitive behaviours and weight gain differ across the childhood years, with the strongest influence of appetite on weight development already established by school-age. Studies with repeated CEBQ and BMI measurements from birth to adolescence are needed to explore this further.

In the present study, BMI *z*-score at 7-years-old was highly associated with BMI *z*-score at 10 years of age this means that children's BMI *z*-score is stable throughout this period. The mean variation of BMI from 7 to 10 years-old was 1.8 kg/m^2. The same is applicable to all appetitive behaviours, although in lower magnitude than for BMI; moderate-to-high associations over time were shown, but with a trend towards children becoming more appetitive, which is in line with previous literature that suggests an increasing likelihood of overeating as children get older [35].

The effect of weight on appetite regulation is complex; several hormonal and neural signals control appetite and energy homeostasis. Leptin, a circulating hormone secreted by adipocytes, plays a major role in the regulation of food intake and fat and glucose metabolism [37, 38]. Leptin seems to be ineffective in obese individuals, resulting in elevated leptin levels, called leptin resistance [39]. Leptin resistance promotes food intake and weight gain [38]. In children, serum leptin concentrations seem to predict greater BMI and fat mass over time [40]. In the current sample, leptin level was positively associated with food approach behaviours and negatively associated with food avoidance behaviours and these associations were mainly observed among children with overweight or obesity (results not showed). Thus, these findings suggest that leptin sensitivity might explain, at least partly, the prospective influence of BMI on appetitive behaviours. It is also important to highlight the effect of dopamine. Dopamine is one of the primary neurotransmitters in the brain—plays a major role in motivated behaviour—and it is involved in the regulation of food intake [41]. Dopamine pathway processes the hedonic and rewarding aspects of food [42]. Studies have shown reduced availability of dopamine receptors in individuals with overweight or obesity [43]. Consequently, there may be less hedonic value in food. This might play a role in food intake, resulting in overeating to obtain the same feelings of reward from food [44]. However, these mechanisms are complex and have been studied only in adults, so may differ in childhood. Besides these biological mechanisms, environmental factors can also influence food intake [45, 46]. It is expected that children with higher weight live in an environment that encourages more eating.

The association between BMI and appetitive behaviours could also be partly explained by certain feeding practices adopted by parents in response to concerns about their child's weight. These feeding practices may influence the development of a child's eating behaviours. Previous studies have shown parents adopt feeding practices in response to characteristics of their child and that these feeding can have an influence on child's appetite [47–51]. However, in our analysis, parental feeding practices did not modify the associations between appetitive behaviours and BMI, failing to support the theory that the effect of BMI on appetitive behaviours varies according to parental feeding practices.

Some strengths and limitations should be considered. The present study includes the use of a large population-based sample and repeated standardized assessments of appetite traits and BMI at two time periods. This allowed a sophisticated modelling, enabling to estimate the magnitude of the associations in both directions, overcoming previous limitations of most cross-sectional and longitudinal studies. However, we recognize that the cross-lagged model combines the between and within person's effect as a single estimate [52]. We could have used other models that separate these two effects, but usually, they include three or more time points and we only have two.

Another possible concern is that children included in the analysis might differ from those of the remaining cohort. As expected, in this sample, the mothers were slightly older and more educated. However, the Cohen effect size ($f2 < 0.20$) was of low magnitude, so these statistical differences are likely due to the large sample size and not to relevant differences between participants [49].

It should be acknowledged too that the CEBQ is a parent-report measure. Parental perceptions and evaluations of their child's appetitive behaviours may be influenced by their child's BMI, such that a child with higher weight may be perceived to have an increasingly avid appetite over time, simply by virtue of their weight. The parent-report nature of the CEBQ may also introduce some measurement error, with parents potentially misreporting due to lack of awareness, social desirability bias, or because of inherent subjectivity. Nevertheless, the CEBQ has previously been validated against behavioural measures of eating and has shown a good internal reliability in this population [25, 26].

Conclusions

In this large population-based cohort, the strongest observed relationships were from BMI at 7 years to appetitive behaviours at 10 years, suggesting children with a higher BMI in middle childhood are at increased risk of developing an avid appetite over time. These findings directly contradict studies in infancy, which report an effect of appetite on weight gain, but they mirror the results of another longitudinal study of appetite and weight across middle childhood. Further longitudinal studies, covering birth to adolescence, are needed to untangle how the relationships between appetite and growth develop across childhood and provide further insight into potential mechanisms.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethics approval All procedures were approved by the Ethical Committee of São João Hospital/University of Porto Medical School and by the Portuguese Authority of Data Protection.

Informed consent Legal representatives of each participant received an explanation of the purposes and design of the study and gave written informed consent at baseline and at each follow-up assessment.

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PAPER II

RELATIONSHIPS BETWEEN PARENTAL FEEDING PRACTICES AND EATING BEHAVIOURS IN CHILDHOOD: A CROSS-LAGGED APPROACH WITHIN THE GENERATION XXI COHORT [UNDER REVIEW]

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ABSTRACT

BACKGROUND: Several studies have linked parental feeding practices and eating behaviours of children. However, longitudinal analyses are limited, and the direction of the associations still needs to be clarified.

OBJECTIVE: We aimed to examine the bidirectional relationships between parental feeding practices and children's eating behaviours from 4 to 7-years-old.

DESIGN: Participants are from the Generation XXI birth cohort, assessed at both 4 and 7 years of age (n=3698 singletons). A validated version of the Child Feeding Questionnaire and the Overt/Covert Control scale were used. Three patterns of parental feeding practices (Perceived Monitoring; Restriction and Pressure to eat) were studied. Children's eating behaviours (eating large amounts of food, eating very slowly and food refusal) were self-reported by parents (measured using dichotomous questions). Cross-lagged analyses were performed to evaluate the direction of the associations (feeding practices at 4y to behaviours at 7y and the reverse) (covariates: child sex, and BMI at 4 y of age and maternal education; plus, the pattern score or the eating behaviour at 4y, according to the direction analysed).

RESULTS: In cross-lagged analyses, eating large amounts of food at 4 years of age was unidirectional associated with higher Restriction three years later ($\hat{\beta}_{standardized}$= -0.047;95%CI=-0.019, -0.075). Apart from this result, all associations had a bidirectional effect of similar magnitude; eating large amounts of food and food refusal at age 4 influence parents to use feeding practices, such as Perceived Monitoring and Pressure to eat at 7 years old, but these practices prospectively influence the development of these eating behaviours too (e.g. $\hat{\beta}_{standardized}$=0.033;95%CI=0.022,0.064 for food refusal at age 4 and Pressure to eat at age 7 and $\hat{\beta}_{standardized}$=0.060; 95%CI=0.034, 0.086, in the reverse direction). Both parental feeding practices and children's eating behaviours showed significant moderate tracking from 4 to 7 years of age (standardized path coefficients ranging from 0.25 to 0.49).

CONCLUSION: Parents and children reciprocally influence each other's behaviour in the context of eating. Our findings suggest a bidirectional relationship between parental feeding practices and children's eating behaviours.

KEYWORDS: feeding practices; eating behaviours; cross-lagged; children; longitudinal.

INTRODUCTION

Parental feeding practices that attempt to dominate, pressure, or impose the parents' will upon the child might have detrimental effects on a child's eating habits (1,2). Some authors hypothesized that these practices may disrupt the child's ability to self-regulate and respond appropriately to their internal cues of hunger or fullness (3,4). In several cross-sectional studies, controlling feeding practices such as restriction of foods have been mostly associated with a tendency to overeat (1) and with higher food responsiveness (representing an interest in eating and a desire to eat) (3,5,6). On the other hand, overly pressuring a child to eat has been associated with food avoidance behavior (3,6). Longitudinal studies do not fully support these relationships. In a sample of 2-to-4-year-old children, modelling of healthy eating was associated with lower food fussiness and a higher interest in food one year later, while pressure to eat was related to a lower interest in food (7). In girls from 5 to 9 years of age, restrictive feeding practices were associated with increased eating in the absence of hunger (measured in a laboratory setting by giving children free access to a variety of palatable snack foods following a standard lunch) (4). Maternal restriction or encouragement to eat at 2 years of age were associated with a tendency to overeat, among other food approach behaviors (such as good appetite and enjoyment of food) one year later (8).

It is difficult to establish a causal relationship between parental feeding practices and children eating behaviors. Parents adapt their feeding practices in response to their child's characteristics, using pressuring practices with children with poor appetite, and restrictive practices with children with an avid appetite (5,9–12), and in response to child weight (13). Additionally, most of the research is cross-sectional, and, therefore, inferences about causality cannot be made.

A few recent studies have tried to elucidate the direction of the associations, and whether parental feeding practices are a predictor or a consequence of children's eating behaviors (14–17). In a Norwegian cohort study (n=797), parental feeding practices predicted eating behaviors from 6 to 8 years of age; no associations in the opposite direction were found. In this study, instrumental feeding (practices such as using food as a reward) was positively associated with emotional overeating and food responsiveness,

while encouragement to eat was associated with increased enjoyment of food (15). A study of 4845 mother-child dyads from the population-based Generation R cohort found bidirectional associations between pressure to eat and food fussiness, from 18 months to 6 years of age (14). In a sample of 207 Australian children, maternal feeding practices predicted food responsiveness from 2 to 5 years old. Associations in the opposite direction were also found, but only for satiety responsiveness (16). Most recently, a study of 479 low-income children reported bidirectional associations between instrumental feeding and food responsiveness from 1 to 3 years of age (17). Emotional feeding was linked to later satiety responsiveness and food responsiveness (17). Although these studies reported mixed findings, it seems that parental feeding practices do impact on children's eating behaviours, but children's eating behaviours also influence the feeding practices parents use. Existing evidence still has some gaps due to an over-reliance on cross-sectional data and studies with small sample sizes limiting generalizability. Furthermore, the bidirectional effect of several feeding practices, some of them highly correlated with eating behaviours, were not evaluated yet. This study aims to explore the direction of the associations between parental feeding practices and eating behaviours across childhood (from ages four to seven), using path analysis in a large population-based prospective cohort.

SUBJECTS AND METHODS

STUDY POPULATION

This study included participants from the population-based birth cohort Generation XXI, described elsewhere (18,19). A total of 8647 liveborn infants were enrolled between April 2005 and August 2006 in all level III public maternity wards from the metropolitan area of Porto (northern Portugal). All families were invited to attend evaluations when children were aged 4 and 7-years-old (86% and 80% participation proportion, respectively). The present study included all children who attended both evaluations (n=6647). Twins (n=238), due to their different feeding dynamics, and children with missing information on variables of interest (parental feeding practices, eating behaviors and potential confounders) were excluded (n=2711) (**Figure 1-Flowchart of participant's selection**), resulting in 3698 participants. In comparing some

maternal and child characteristics from the study sample with the remaining cohort at baseline (n= 8647), the mothers were slightly older (mean= 29.0, SD= 5.6 vs mean= 30.0, SD= 5.1 years, $p < 0.001$) and more educated (mean= 10.5, SD= 4.3 vs mean= 11.4, SD= 4.3 years of education, $p < 0.001$). According to Cohen's effect size values (20), the magnitude of differences was not high (0.13 for maternal age and 0.42 for maternal education), suggesting that these statistical differences are likely due to the large sample size and not to systematic differences between participants.

This study was conducted according to the principles of the Declaration of Helsinki and all procedures were approved by the Ethical Committee of São João Hospital/University of Porto Medical School and by the Portuguese Authority of Data Protection. Legal representatives of each participant received an explanation of the purposes and design of the study and gave written informed assent at baseline and each follow-up assessment.

DATA COLLECTION

PARENTAL FEEDING PRACTICES

Parental feeding practices were measured using a combined version of the Child Feeding Questionnaire (CFQ) (21) and the scales of overt and covert control (22), self-completed by parents or main caregivers (93.2% and 95.3% fulfilled by mothers, at 4 and 7 years old respectively). This version was previously adapted and validated for Portuguese preschool children (23). In our sample, at both time points, Cronbach's alpha coefficients for each subscale were calculated to assess the internal consistency. At 4 years of age, it ranged from 0.69 to 0.89 and at 7 years it ranged from 0.71 to 0.89. A good fit was also observed at 7 years of age and a fair to moderate reproducibility (13). Parental feeding practices were evaluated through the following subscales: perceived responsibility for feeding (three items), perceived parent weight (four items), perceived child weight (three items), concerns about child weight (three items), restriction of child's access to food (three items), pressure to eat more foods (five items), monitoring the child eating (three items), overt control (which can be perceived by the child, four items), and

covert control (when the child cannot detect it, five items). Answers were given on a 5-point Likert scale, with higher scores indicating higher levels in each subscale.

CHILDREN'S EATING BEHAVIOUR

Three eating behaviours were evaluated according to the perception of the parents: eating very slowly, eating large amounts of food and food refusal. Eating very slowly and eating large amounts of food were assessed using a dichotomous question (Yes vs No). To evaluate food refusal, a combined variable was created (refuse to eat fruits and vegetables, soup and fish). The final score ranges from 0 (does not refuse foods) to 3 (refuse all the foods). These questions were adapted from the subscales of the Children's Eating Behaviour Questionnaire (CEBQ) (24) (the full version of this questionnaire was not applied at age 4). The CEBQ was validated in Generation XXI at 7 years of age (25) and the correlation between the variables and the corresponding sub-domains (Food Fussiness, Slowness in Eating and Food responsiveness) was tested. The point-biserial correlations were moderate to high: rho = 0.665 ($p < 0.001$), rho = 0.447 ($p < 0.001$), and rho = 0.440 ($p < 0.001$), respectively, for the three behaviours referred.

CO-VARIATES

Childbirth weight was retrieved from clinical records at baseline. At 4 and 7 years old, anthropometric measurements were performed by trained staff using standard procedures (26). Children Body Mass Index (BMI) was classified according to the age- and sex-specific BMI standard z-scores developed by the World Health Organization (WHO) (27). At the 4 years old follow-up, maternal weight and height were measured and BMI was defined as weight in kg divided by squared height in meters. At the same follow-up, maternal age and educational level were recorded as completed years of ageing and schooling.

STATISTICAL ANALYSIS

Due to the high correlation between feeding practices, the five subscales of the CFQ related to feeding (perceived responsibility, concern about child weight, restriction, pressure to eat and monitoring) and the overt/covert control measures were studied by principal component analysis (PCA) to identify patterns of parental feeding practices at

both ages, independent of each other. It used the same methodology as described elsewhere (28). At both ages, the suitability of data for factor analysis was assessed. The correlation matrix revealed a few coefficients higher than 0.30. The Kaiser-Meyer-Olkin value was 0.648 at age 4 and 0.626 at age 7, and Bartlett's test of sphericity reached statistical significance ($p<0.001$), supporting the factorability of the correlation matrix. Varimax rotation was performed to simplify the interpretation of factor's loadings structure. Kaiser's criterion was chosen to select only eigenvalues greater than one determining the number of components (29). The items with an absolute factor loading of 0.3 or higher were interpreted as having a meaningful part in each factor.

A cross-lagged analyses were performed to test bidirectional associations, from 4 to 7 years of age, between parental feeding practices and eating behaviours. Each model included simultaneously: i) cross-lagged paths from parental feeding practices to eating behaviours and the reverse, ii) auto-regressive paths (tracking) for each variable and iii) cross-sectional correlations between variables at the two-time points (4 and 7 years of age). Standardized $\hat{\beta}$-regression coefficients were used to determine the relative strength of the examined associations, and the 95% confidence intervals (95% CI) were used to determine the statistical significance of those associations. Potential confounders were tested in linear regression models and those that were not associated with the outcome or did not change the associations of interest were not considered in the analysis (child's birth weight, maternal age and maternal BMI at 4 years follow-up). All associations were adjusted for child sex and BMI at 4 years of age and maternal education. A Comparative Fit Index (CFI) and a Tucker-Lewis Index (TLI) ≥0.90, a Root Mean Square Error of Approximation (RMSEA) close to 0.06 and a standardized root mean square residual (SRMR) close to 0.08 were used as criteria to support the goodness of models' fit (30–32). Statistical significance was determined at a level of $P \leq 0.05$. Descriptive statistics were performed in SPSS software 25.0. and the cross-lagged analyses were conducted using R 3.0.1 statistical software.

RESULTS

Characteristics of mothers and their children are presented in **Table 1**. At the 4 years old follow-up, mothers had a mean age of 34.9 years (standard deviation SD=8.1),

11.7 mean years of education (SD=5.4) and a mean BMI of 26.3 kg/m2 (SD=5.0). Children were 48.4% girls, with a mean birth weight of 3187 (SD=482) grams. Children BMI z-score was slightly higher at 7 years old. Around 11% of the mothers at age 4 and 20% at age 7 reported that their child usually eats large amounts of food. About 50% also had the perception that their child eats very slowly, at both ages. At age 4, 5.3% of the children refused all food considered (fruits and vegetables, soup and fish), at age 7 this percentage increased to 7.5%.

Parental feeding practices were summarized using PCA, and a three-factor solution was extracted, explaining 58% of the total variance at 4 years of age and 60% at 7 years of age (Table 2). The findings were similar at both ages. Monitoring, perceived responsibility and overt control loaded onto factor 1 (Perceived Monitoring). Concerns about child weight, covert control and restriction loaded onto factor 2 (Restriction). Pressure to eat and overt control loaded onto factor 3 (Pressure to eat) at 4 years of age, but at 7, concern about child weight also loaded in this component.

A cross-lagged modelling approach was performed to compare the associations in both directions (from parental feeding practices to children eating behaviours and the reverse) (Table 3 and Figure 2). The models had an acceptable fit, as demonstrated by the fit indexes provided for each model. All the variables (either feeding practices or eating behaviours) showed significant stability over time (standardized path coefficients ranging from 0.25 to 0.49). Most models had significant associations in both directions, parental feeding practices predicting eating behaviours and the reverse.

From 4 to 7 years of age, Perceived Monitoring was significantly and inversely associated with eating large amounts of food ($\hat{\beta}$standardized = -0.049; compared with $\hat{\beta}$standardized = -0.056 in the reverse direction), with similar effects in both directions (overlapping confidence intervals). Perceived Monitoring at 4 years of age was also associated with less food refusal at 7 years old ($\hat{\beta}$standardized = -0.042), but the reverse was verified too ($\hat{\beta}$standardized = -0.054). No significant associations were found between Perceived Monitoring and eating very slowly.

Those children who at 4 years of age were eating large amounts of food had parents using more Restriction at 7 years of age ($\hat{\beta}$standardized =0. 047). There was no

association in the opposite direction. No significant cross-lag paths were found between Restriction and the other eating behaviours (such as eating very slowly and food refusal).

All the relationships between Pressure to eat and children's eating behaviours had a bidirectional effect. More Pressure to eat at 4 years of age was associated with less eating large amounts of food at 7 years old ($\hat{\beta}$standardized = -0.096), and those children who at 4 years old were eating large amounts had parents using lower pressure feeding practices at age 7 ($\hat{\beta}$standardized = -0.044). Conversely, Pressure to Eat was positively associated with eating very slowly ($\hat{\beta}$standardized = 0.086) and the same was observed for the reverse direction ($\hat{\beta}$standardized = 0.074). A similar association was found with food refusal ($\hat{\beta}$standardized = 0.033) and ($\hat{\beta}$standardized = 0.060 in the opposite direction), i.e. eating slowly and food refusal were associated with more Pressure to eat from 4 to 7 years old.

DISCUSSION

Our findings suggest that parents and children reciprocally influence each other's behaviour in the context of eating. Eating large amounts of food at 4 years of age was associated with a higher level of Restriction three years later, apart from this result all associations had a bidirectional effect of similar magnitude.

We found that parents of children who eat large amounts of food use more Restriction feeding practices (characterized by higher covert control, restriction, and concern about child weight). Jansen et al., using a cross-lagged modelling approach covering three time points, found an association in the opposite direction. Covert restriction (a type of restriction that cannot be detected by the child, similar to covert control) at age 2 predicted lower food responsiveness (measured by the CEBQ [21], somewhat comparable to eating large amounts of food in our study) at 3.7 years. However, there was no association from 3.7 to 5 years of age, which might suggest that this association could be stronger in younger ages. Webber et al., in a sample of 231 British children, found similar results to ours (5). In this study, food responsiveness at age 7 was positively associated with restriction at age 9 (5). Studies evaluating the association between restriction and weight across childhood have shown that restriction is a response of parents to child weight, rather than a cause of a child becoming overweight

(13,33). Based on these findings, it can be speculated that parents use restrictive feeding practices as an attempt to control food consumption when they believe that the child is eating too much, as found in our study, or as a reaction to a child having overweight.

Perceived Monitoring (defined by higher levels of monitoring, perceived responsibility and overt control, a control perceived by the child) was negatively associated with eating large amounts of food and food refusal in both directions. This suggests that parents of children who eat large amounts of food or refuse to eat were less likely to monitor their children's eating habits. On the other hand, higher levels of Perceived Monitoring were negatively associated with these eating behaviours, indicating that this practice might have positive prospective effects. A study of 323 infants found that maternal monitoring at age 2 was negatively associated with food approach behaviours and a tendency to overeat one year later (8), which are in line with our results. To the best of our knowledge, no longitudinal studies have evaluated the relationship between food refusal and monitoring.

Pressure to eat (characterized by higher levels of pressure to eat and overt control) was also associated in both directions with children's eating behaviours. Eating very slowly and food refusal were positively associated with this practice, while eating large amounts of food was negatively associated. Regarding food refusal, our results are in accordance with a study from the Generation R cohort; using a cross-lagged model, the study found a bidirectional relationship between food fussiness (somewhat comparable to food refusal) and pressure to eat from 4 to 6 years of age (14). Several cross-sectional studies have linked pressure to eat and food avoidance behaviours (which reflect an avoidant eating style characterized by a lower appetite and interest in food and greater food fussiness) (1,5,6,34); however, longitudinal analyses are limited. Analysing the association from eating behaviour to feeding practice, Webber et al., reported that food fussiness and slowness in eating at age 7 were associated with higher use of pressuring strategies three years later (5). In line with this, a siblings' study with children aged approximately 5 years old, found that parents used different feeding practices for children in the same family in response to their eating behaviours, placing higher levels of pressure to eat on fussier children (11). Another study with a within-family design showed that at 16 months, infants with higher levels of food fussiness were more

pressured to eat (10). Together, these findings support the notion that parents adapt their feeding practices in reaction to the eating behaviours of their children. Parents want their children to achieve what they perceive as the best outcomes regarding weight and healthy eating. Therefore, in response to the perception that a child is eating very little, they try to get their child to eat more, probably driven by concerns about nutrient deficiencies and the child having underweight (35). On the other hand, our results do not support the hypothesis that pressuring practices may disrupt the child's ability to self-regulate their intake of food (3,4). Instead, they suggest that pressuring feeding practices used by parents to increase their child's intake of food might contribute to the persistence of food avoidance behaviours. Studies which focus on food intake also provide some evidence that this practice may be counterproductive, showing an association with less healthy dietary habits (36) and with a reduced intake of foods which parents specifically pressure their child to eat (37). Regarding the associations with BMI, it seems that the use of Pressure to eat is more likely a reaction to a child being underweight (13,38). These results are consistent with the assumption that parents use Pressure to eat in response to the child's characteristics and behaviours, but this action might have unintended effects.

Previous literature shows that parental feeding practices (39,40) and eating behaviours (41,42) are fairly stable over time, our results are in accordance with this, we found a significant moderate tracking from 4 to 7 years of age.

Some strengths and limitations should be considered. An obvious strength includes the use of a large population-based sample and repeated standardized assessments of parental feeding practices. Further, parental feeding practices were analysed as independent patterns rather than single dimensions, clarifying the relative contribution of the different feeding practices used with children. Parents use a combination of practices in feeding; thus, assessing the single effect of a dimension might be confounded by other practices. It should be noted, however, that the maternal self-report measures might have biased the results. Self-report is known to introduce a few errors, with parents potentially misreporting because of a lack of awareness, social desirability bias, or because of inherent subjectivity. Studies comparing self-reported feeding practices with independent observations have found poor associations between

the two measures (43,44). Nevertheless, the CFQ has been widely used and was previously validated in our sample (13). Additionally, most questionnaires (more than 90%) were answered by mothers and it has been suggested that fathers and mothers may use different feeding practices (45). Studies evaluating the feeding fathers' practices are extremely limited (2); additional information from fathers could give more insight into the feeding strategies within families. Another limitation to point out is that the children's eating behaviours (eating large amounts of food and eating slowly) were measured with a single question rather than comprehensive scales. For food refusal, a composite variable was calculated. Thus, these variables are highly dependent on parental perceptions and might not capture the actual behaviour. This might have impaired the detection of further associations, and the possibility of misreporting cannot be discarded. However, the questions used were derived from the CEBQ, showing moderate-to-high correlations with the original sub-domains of this scale, which has shown good internal reliability in this population (25). Additionally, the cross-lagged analyses allowed for sophisticated modelling, enabling to estimate the magnitude and direction of the associations. However, it has also a few limitations, such as the combination of the between-and within-person's effect as a single estimate (46).

In conclusion, our results highlight that the relationships between parental feeding practices and children's eating behaviours are highly complex, and parents and children mutually influence each other's behaviours. Eating large amounts of food, eating slowly, and food refusal during childhood can influence parents to have specific feeding practices; however, these practices prospectively influence the development of these eating behaviours as well. The single unidirectional relationship found was between the Restriction at 7 years old in response to eating large amounts of food at 4 years old. To clarify these relationships, it is important to perform additional longitudinal studies from infancy to adolescence, exploring the temporal direction and effects of these complex associations.

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TABLE 1 Characteristics of study participants (n=3698)

Maternal characteristics at 4 years old follow-up, mean (SD)		
Age (y)	34.9(8.1)	
Educational level (y)	11.7(5.4)	
BMI (kg/m^2)	26.3(5.0) [a]	
Child characteristics		
Birthweight, mean (SD)	3187(481.6)	
Sex, n (%)		
Girls	1791(48.4)	
Boys	1907(51.6)	
zBMI, mean (SD)	**4y**	**7y**
	0.59(1.1)	0.70(1.2)
Children eating behaviours	**4y**	**7y**
Eat large amounts of food, n (%)	403(10.9)	724(19.6)
Eat very slowly, n (%)	1919(48.1)	1977(53.5)
Food refusal, n (%)		
Refuse all foods[b], n (%)	195(5.3)	273(7.5)
Do not refuse any food, n (%)	1487(40.3)	1158(31.9)

BMI: Body mass index; y: years old; SD: standard deviation. [a]n= 3500 due to missing values.[b] Foods considered: vegetables and fruit, soup and fish.

TABLE 2 Descriptive statistics and factor's loadings of the adapted version of the Child Feeding Questionnaire at 4 a and 7 years of age b, obtained from principal component analysis *

Subscales			Perceived Monitoring		Restriction		Pressure to eat	
	Mean (SD)		Factor loadings					
	4y	7y	4y	7y	4y	7y	4y	7y
Perceived responsibility	4.35(0.6)	4.35(0.6)	**0.66⁺**	**0.69⁺**	0.02	-0.02	0.02	0.11
Concern about child weight	2.35(1.1)	2.29(1.1)	0.03	-0.01	**0.70⁺**	**0.68⁺**	-0.28	**-0.40⁺**
Restriction	4.35(0.7)	4.34(0.8)	0.22	0.17	**0.66⁺**	**0.69⁺**	0.12	0.17
Pressure to eat	3.6(0.96)	3.56(1.1)	0.09	0.09	0.02	0.07	**0.87⁺**	**0.91⁺**
Monitoring	4.2(0.77)	4.24(0.7)	**0.78⁺**	**0.75⁺**	0.01	-0.01	-0.24	-0.14
Overt control	4.1(0.6)	4.15(0.6)	**0.60⁺**	**0.66⁺**	0.22	0.26	**0.41⁺**	**0.30⁺**
Covert control	3.2(0.8)	3.10(0.8)	-0.07	-0.02	**0.69⁺**	**0.71⁺**	0.19	0.09
Eigenvalue			1.47	1.52	1.47	1.52	1.17	1.14
% of variance explained			21.0	22.0	21.0	22.0	17.0	16.0
% of cumulative variance explained			21.0	22.0	42.0	43.0	58.0	60.0

SD, standard deviation; y, years old. * Varimax rotation of three-factor solution. ⁺ Factor loading >0.30. [a]Five subscales of the Child Feeding Questionnaire and the Overt/Covert control were previously tested in Portuguese children. [b] Results at 7y are newly described here; results at 4y were previously published (28).

TABLE 3 Longitudinal paths between parental feeding practices and children eating behaviours from 4 to 7 years of age (n=3689)

	Feeding Practices at 4 y to Eating Behavior at 7 y	Eating Behavior at 4 y to Feeding Practices at 7 y	Feeding Practice from 4 to 7 y	Eating Behavior from 4 to 7y
	standardized β̂ (95%CI)	standardized β̂ (95%CI)	standardized β̂ (95%CI)	standardized β̂ (95%CI)
Perceived Monitoring				
Eat large amounts	**-0.049 (-0.078, -0.020)**	**-0.056 (-0.087, -0.025)**	**0.393 (0.366,0.420)**	**0.248 (0.218,0.2789**
Eat slowly	-0.003 (-0.032,0.026)	-0.027 (-0.057,0.003)	**0.401 (0.374,0.428)**	**0.316 (0.288,0.345)**
Food refusal	**-0.042 (-0.072, -0.013)**	**-0.054(-0.083, -0.025)**	**0.362 (0.335,0.390)**	**0.386 (0.359,0.413)**
Restriction				
Eat large amounts	-0.011 (-0.019,0.041)	**0.047 (0.019,0.041)**	**0.490 (0.465,0.514)**	**0.251 (0.222,0.281)**
Eat slowly	-0.019 (-0.048,0.011)	-0.010 (-0.038,0.017)	**0.490 (0.466,0.515)**	**0.314 (0.285,0.343)**
Food refusal	0.013 (-0.017,0.043)	-0.009 (-0.035,0.018)	**0.486 (0.462,0.510)**	**0.367 (0.339,0.394)**
Pressure to eat				
Eat large amounts	**-0.096 (-0.126, -0.065)**	**-0.044 (-0.071, -0.016)**	**0.436 (0.410,0.461)**	**0.242 (0.212,0.272)**
Eat slowly	**0.086 (0.055,0.117)**	**0.074 (0.047,0.102)**	**0.426 (0.400,0.452)**	**0.301 (0.272,0.330)**
Food refusal	**0.033 (0.022,0.064)**	**0.060 (0.034,0.086)**	**0.442 (0.417,0.467)**	**0.364 (0.336,0.391)**

Values are the longitudinal paths of the cross-lagged models, representing standardized β̂-regression coefficients with corresponding 95% Confidence Intervals. Each model includes cross-sectional correlations at each time point. All associations are adjusted for child sex, and BMI at 4 years of age and maternal education. Significant results ($p < 0.005$) are shown in bold font.

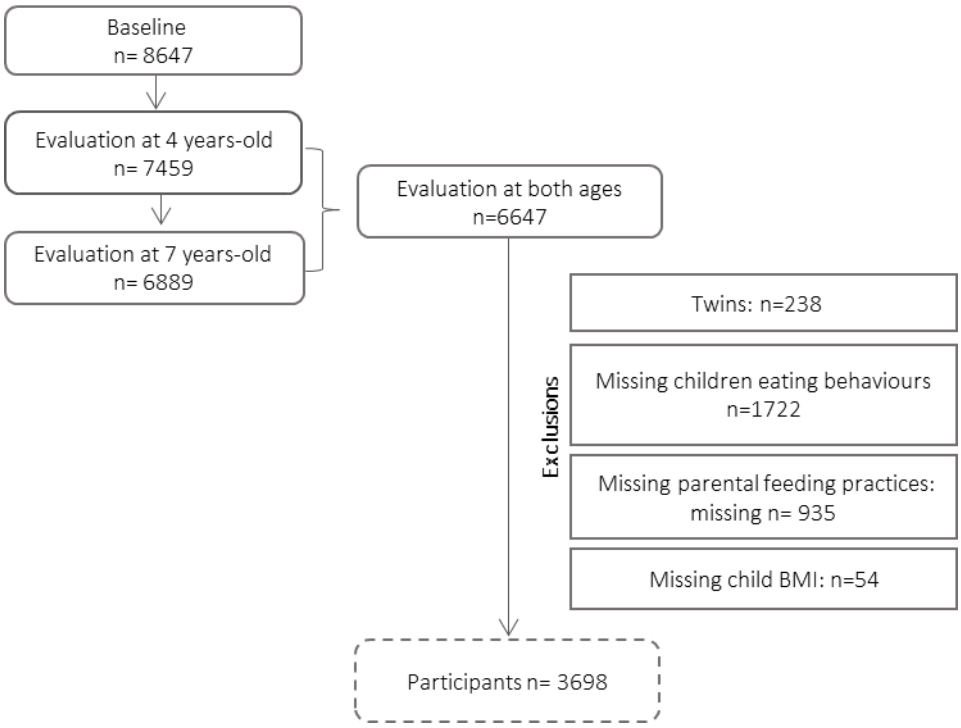

FIGURE 1 Flowchart of participant's selection

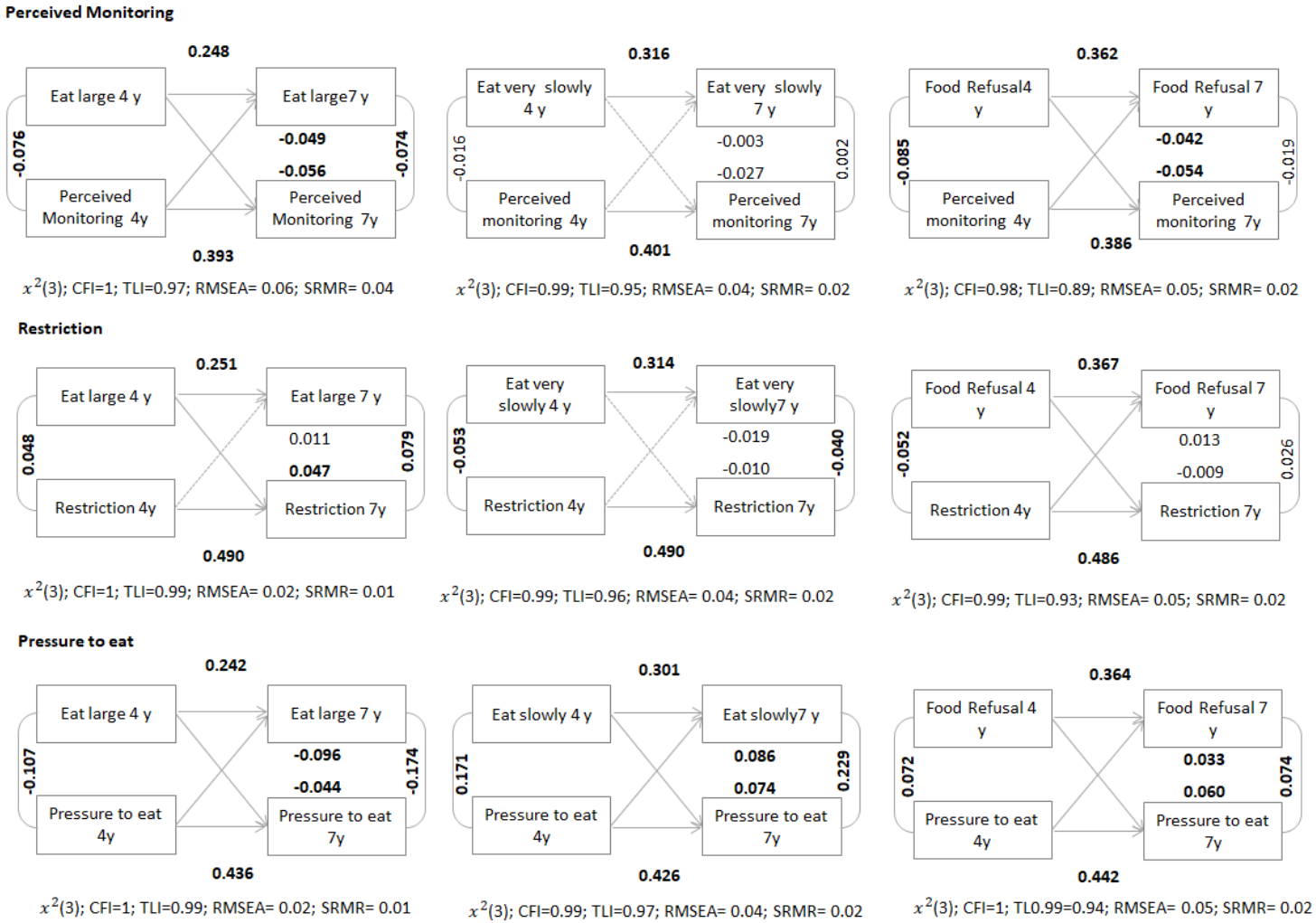

FIGURE 2 Cross-lagged models on the associations between children eating behaviours and parental feeding practices. For longitudinal associations, values represent standardized β̂-regression coefficients. All associations are adjusted for child sex, and BMI at 4 years of age and maternal education. Significant results (p <0.05) are shown in bold font. CFI, comparative fit index, RMSEA, root mean square error of approximation, SRMR, standardized root mean square residual, TLI, Tucker–Lewis index; y; years old

PAPER III

MATERNAL PERCEPTION, CONCERN AND DISSATISFACTION WITH CHILD WEIGHT AND THEIR ASSOCIATION WITH FEEDING PRACTICES IN THE GENERATION XXI BIRTH COHORT [SUBMITTED FOR PUBLICATION]

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ABSTRACT

BACKGROUND: What a mother thinks about her child weight status, perceiving healthy or overweight might influence concern about child weight and in turn what and how she feeds her child.

OBJECTIVES: To examine the association between maternal perception, concern and dissatisfaction with child weight alongside feeding practices (at 4 and 7 years of age).

DESIGN: Participants were from the Generation XXI birth cohort (n=3233). A validated version of the Child Feeding Questionnaire and the Overt/Covert Control scale were used. Mothers self-reported their perception, level of concern about weight gain and dissatisfaction with child weight using a Likert scale. Associations were cross-sectionally evaluated at 4 and 7 years of age by linear regression models (covariates: maternal education, child sex and BMI).

RESULTS: Mothers whose children have overweight/obesity frequently failed to identify this (83.8% at 4 and 70.3% at 7 years). Perceived underweight was associated with practices promoting food intake, such as higher pressure to eat at 4 and 7 years of age ($\hat{\beta}$=0.234,95%CI:0.243,0.486 and $\hat{\beta}$=0.329,95%CI:0.199,0.459, respectively) and lower restriction at 7 years old ($\hat{\beta}$=-0.114,95%CI:-0.217,-0.010). Perceived overweight was consistently associated with feeding practices at 7 years of age including covert control ($\hat{\beta}$=0.279,95%CI:0.170,0.389), overt control ($\hat{\beta}$=-0.081; 95%CI:-0.157,-0.006), pressure to eat ($\hat{\beta}$=-0.272,95%CI:-0.401,-0.143) and monitoring ($\hat{\beta}$=-0.102;95%CI:-0.193,-0.010). Mothers who were concerned about child weight reported higher levels of restriction ($\hat{\beta}$=0.241,95%CI:0.178,0.30 and $\hat{\beta}$=0.279,95%CI:0.206,0.339 at 4 and 7 years old, respectively) and covert control ($\hat{\beta}$=0.187,95%CI:0.112,0.261 and $\hat{\beta}$=0.185,95%CI:0.113,0.257, respectively). Maternal desire for a heavier child was associated with higher pressure to eat, while the desire for a thinner child was related to lower pressure and monitoring ($\hat{\beta}$=-0.320,95%CI:-0.465,-0.174 at 4 and $\hat{\beta}$=-0.142,95%CI:-0.269,-0.015 at 7 years).

CONCLUSIONS: Maternal perceptions and concern for child weight status are associated with maternal feeding practices independently of actual weight status. Associations were more consistent and stronger at 7 than at 4 years of age.

KEYWORDS: children; feeding practices; maternal perception; maternal concern; weight.

INTRODUCTION

Childhood is a critical period in the development of obesity (1). Parents are responsible for the food environment and eating experiences for their children (2–4). Feeding strategies used by parents aiming to control or modify their child food intake have been the focus of several research studies (5–10). A relationship between parental feeding practices and the food consumption (5,6), eating behaviors (7,8,11), and weight (9,10) of children has been suggested. In particular, controlling or restrictive feeding practices are potentially problematic and can be associated with obesogenic eating behaviors and less healthy food consumption (5,6,8,11).

Parental feeding practices are influenced by many factors, such as the family's socioeconomic and psychological characteristics, as well as parental perceptions of those characteristics (8,10,12–14). Specifically, previous research has shown that maternal perceptions or concerns with their children's weight influence feeding practices (13,15–21). In toddlers, preschoolers and school-aged children, maternal concern about child becoming overweight was cross-sectionally associated with greater restrictive and pressuring feeding practices (17,19,20,22). There is considerable evidence that mothers misjudge their child weight status. In general, mothers tend to underestimate their child weight status, failing to recognize excessive weight (23,24). Mothers who perceive their child as having overweight/obesity report higher levels of restriction and lower levels of pressure to eat (19,25–27). On the other hand, mothers who perceive their child as underweight are more likely to pressure their child to eat more (17,19,25,27).

As maternal feeding practices are modifiable risk factors for problematic child diet-related outcomes, understanding their underlying factors may offer valuable insights for tailored interventions to improve child health. To our knowledge, studies only have evaluated the association between maternal perception of weight and feeding practices at one-time point and using children from a broader age-range, thereby it makes it difficult to explore age differences. A further topic of limited research is the stability of maternal perception and concern across time. Additionally, most studies have relied on relatively small sample sizes (13,15–21,28,29), and only a few have evaluated weight perception and concern about child weight simultaneously (16,17,19). Weight

perception might not influence feeding practices unless parents are also concerned about their child weight, so it is crucial to study these concepts in tandem. Furthermore, a concept that is often neglected is the extent to which mothers are dissatisfied with their child body weight. Mothers who are dissatisfied with their weight may use controlling feeding practices (30), but the direct relationship between maternal dissatisfaction with child weight and feeding practices is less well understood. Overall, since the mother is principally responsible for what and how a child is fed in the early years, it is important to consider how her perceptions and concerns about child weight might influence the ways in which she feeds her child.

Therefore, using data from a large population-based prospective cohort, the aim of the present investigation was to examine the association between maternal perception, concern and dissatisfaction with child weight and feeding practices at two time points (at 4 and 7 years of age). Our secondary aim was to analyze the stability of maternal cognitions about child weight from 4 to 7 years of age. We hypothesized that mothers who perceive their children as having overweight and who are concerned or dissatisfied with their child weight would report more restrictive and controlling feeding practices.

METHODS

STUDY POPULATION

This study included participants from a population-based birth cohort Generation XXI, described elsewhere. (31,32) A total of 8647 liveborn infants were enrolled between April 2005 and August 2006 in all level III public maternity wards from the metropolitan area of Porto (northern Portugal). All families were invited to attend evaluations when children were aged 4 and 7-years-old (86% and 80% participation proportion, respectively). The present study included all children who attended both evaluations (n=6647). Twins (n=238) and children with missing information on variables of interest (i.e. maternal feeding practices, weight perception and concern about weight gain and potential confounders) were excluded (n=3176), resulting in a final sample of 3233. The inclusion and exclusion flowchart of participants is available in **Figure 1**. Comparison of baseline characteristics between this sample and the remaining cohort (non-participants) showed

that mothers in the present sample were slightly older (mean=29.2 years; SD=5.7 compared with 29.9 years; SD=5.0) and more educated (mean=10.0 complete schooling years; SD=4.2 compared with 11.8 complete schooling years; SD=4.2). According to Cohen`s effect size values (33), the magnitude of differences was not high (0.13 for maternal age and 0.42 for maternal education), suggesting that these statistical differences are likely due to the large sample size and not to systematic differences between participants.

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving were approved by the Ethical Committee of São João Hospital/University of Porto Medical School and by the Portuguese Authority of Data Protection. Legal representatives of each participant received an explanation of the purposes and design of the study and gave written informed assent at baseline and each follow-up assessment.

MEASURES

FEEDING PRACTICES

Feeding practices were measured using maternal self-report when their child was aged 4 and again at age 7 years. A combined version of the original Child Feeding Questionnaire (CFQ) (34) and the scales of overt and covert control devised by Ogden et al. were used (35). This version was previously adapted and validated for Portuguese preschool children from Generation XXI (36). At 7 years of age, this adapted version also showed a good fit and a fair to moderate reproducibility (10). Maternal feeding practices included the following subscales: restriction (the extent to which parents control the child's access to foods or opportunities to consume those foods) (3 items), pressure to eat (parents' insistence or demands that their children eat more food) (4 items), monitoring (the extent to which parents track what and how much the child is eating) (3 items), overt control (represented by a firm attitude from parents about what, how much, where, and when the child eats, which can be perceived by the child) (5 items), and covert control (in which the child is unable to detect the control; for example, avoiding buying energy-dense foods) (4 items). Answers were given on a 5-point Likert scale, with higher

scores indicating higher levels in each subscale. In our sample, at both time points, Cronbach's alpha coefficients for each subscale were calculated to assess the internal consistency, at 4 years of age ranged from 0.69 to 0.89 and at 7 years ranged from 0.71 to 0.89.

MATERNAL PERCEPTION OF CHILD CURRENT WEIGHT AND CONCERN ABOUT CHILD WEIGHT GAIN

Perception of child current weight status was assessed at both ages by a single question: ´How would you describe your child's weight currently? `, with response options of: 'Very underweight,' 'Underweight', 'Normal weight', 'Overweight' and 'Very overweight'. Further, due to the relatively low sample size in the two extreme categories, 'Very underweight' (n= 16 at 4 years n= 20 at 7 years) and Very Overweight (n=14 at 4 years and n=20 at 7 years), these categories were combined with 'Underweight' and 'Overweight', respectively. Concern about child weight gain was assessed using the item: ´How concerned are you about your child becoming overweight? `, with response options of: ´Not concerned`, 'A little concerned', 'Concerned', 'Quite concerned', 'Very concerned'. Responses were dichotomized into 'unconcerned' and 'concerned' (a little concerned, concerned, quite concerned, very concerned). Both items were derived from the CFQ (34), which was tested in our sample (as previously described)10,3(10,36).

SATISFACTION WITH CHILD BODY WEIGHT

Maternal satisfaction with child body weight was evaluated at 4 years of age by a single question: ´Do you think the weight of your child is adequate for his/her age and height?' with response options of: 'No, my child should weigh more', 'No, my child should weigh less', 'Yes'. At 7 years of age, mother's satisfaction with child body size was assessed using a figure rating scale (37). Mothers were presented with nine gender-specific figures of increasing size, each designated with a numerical rating. Mothers indicated the figure they felt best reflected their child's current body size and their child's ideal body size. Satisfaction with child body size was calculated as the silhouette number indicated as ideal subtracted from the silhouette number indicated as current (perception); a negative score indicated that mothers considered that their child should weigh more; a zero represented satisfaction with child body size; a positive score indicated that mothers considered that their child should weigh less.

Co-variates

Anthropometric measurements were performed by trained staff using standard procedures (38). Children's Body Mass Index (BMI) was classified according to the age- and sex-specific BMI standard z-scores developed by the World Health Organization (WHO)(39). The WHO cut-offs for weight status categories differ for children 0-5 years old and 5-19 years old. In the current sample, given the proximity of children's age to 5 years, the same cut-offs were used for children at 4 and 7 years, i.e. underweight (-≤2 SD), normal weight (- 2 SD to 1 SD), overweight (1 SD to 2 SD) and obese (≥2 SD). Overweight and obese categories were collapsed for data analysis. Clinical records were reviewed at birth to retrieve data on birthweight. Country of birth of the mothers was assessed as an open question and transformed into a categorical variable (Portuguese; non-Portuguese). Maternal BMI was defined as weight in kilograms divided by squared height in meters. Maternal age and education were recorded as completed years of ageing and schooling. Household monthly disposable income was collected as a categorical variable (<500, 500–1000, 1001–1500, 1501–2000, 2001–2500, 2501–3000, >3000 euros) and further grouped into four ordinal categories.

Statistical Analysis

The descriptive statistics are presented as means and standard deviations (SD) for continuous data, or numbers and percentages for categorical data. To assess the stability of maternal variables from 4 to 7 years of age kappa coefficients were calculated (40). McNemar's or Bowker's test were used to assess change in proportions over time. The association of maternal weight perception, concern about child weight gain and dissatisfaction with child body weight (independent variables) with feeding practices (dependent variables) were assessed by regression coefficients ($\hat{\beta}$) and the respective 95% confidence intervals (95%CI) estimated by linear regression models. Several potential confounders were individually assessed in each model for each feeding practice, but those that did not change the magnitude of the associations of interest were not included in final analyses (maternal age, country of birth of the mother, maternal BMI, birthweight and household income). Two different models for each feeding practice are presented: the first model shows the unadjusted results (model 1); the second model, considered as the final model, is adjusted for maternal education, child sex and BMIz at

4 or 7 years of age (model 2). Interaction of the child sex in these associations was tested by including an interaction term in the final models, but no significant interaction was found. Thus, results are reported for all children. The consistency between the exposure variables (maternal perception, concern and dissatisfaction with child weight) was also assessed to see if a unique construct would be feasible to calculate, but the Cronbach-alpha of 0.263 at 4 and 0.290 at 7 did not support that, thus they were independently studied.

Statistical analysis was conducted using SPSS statistical software package version 26 (SPSS Inc., Armonk, NY, USA) and a significance level of 5% was adopted.

RESULTS

Characteristics of mothers and their children are presented in Table 1. The mean age of mothers at baseline was 29.9 years, their mean education was 11.8 complete schooling years, and their mean BMI at 4 years of age follow-up was 26.3 kg/m2. Fifty-one percent of children were boys, and the percentage of children with overweight or obesity slightly increased from 4 to 7 years of age (from 31.5% and 35.1%, respectively).

At both ages, about 80% of the mothers reported that they were concerned that their child would become overweight (Table 2). The agreement between answers at 4 and 7 years of age was moderate (k=0.475, p<0.001); only 17% of mothers changed their view. Regarding dissatisfaction with child body weight at 4 years of age, 75% of mothers were satisfied and only 7% considered that their child should weigh less. At 7 years of age, a higher percentage desired a larger (24%) or slimmer body size (15%) for their child. There was only a slight agreement between classifications at 4 and 7 years (k=0.346, p<0.001); with almost 30% reporting a change in their level of satisfaction. Maternal concern and dissatisfaction with child weight by weight category of the child are presented in the Supplemental Table 1.

Most mothers rated their child as having a normal weight (87% at 4 years old and 80% at 7 years old) and moderate agreement was observed between classifications across time (k=0.404, p<0.001). Figure 2 shows that at 4 years of age, 83% of mothers whose

child had overweight did not identify this in their child. This percentage decreased to 70% by 7 years of age.

Table 3 presents the results of the associations between maternal perception, concern and dissatisfaction with child weight and maternal feeding practices at 4 years of age, and Table 4 shows the same associations three years later. In multivariate analysis (model 2 fully adjusted), mothers who rated their child weight status as underweight reported significantly higher levels of pressure to eat at both 4 and 7 years of age ($\hat{\beta}$=0.364; 95%CI: 0.243, 0.486 and $\hat{\beta}$=0.329; 95%CI: 0.199, 0.459, respectively), and lower restriction at 7 years of age ($\hat{\beta}$=-0.114; 95%CI: -0.217, -0.010), compared to mothers who rated their child's weight status as normal. Conversely, perceived child overweight was associated with lower levels of pressure to eat ($\hat{\beta}$=-0.333; 95%CI: -0.490, -0.177 at 4 years old; $\hat{\beta}$=-0.272; 95%CI: 0.199, -0.143 at 7 years old). At 7 years of age, mothers who rated their child as overweight also reported significantly lower levels of overt control ($\hat{\beta}$=-0.081; 95%CI: -0.157, -0.006) and higher levels of covert control (model 2: $\hat{\beta}$=0.279; 95%CI: 0.170, 0.389). Regarding concern about child weight gain, similar associations were observed at both ages, mothers who rated themselves as concerned about their child becoming overweight reported higher levels of restriction ($\hat{\beta}$=0.241; 95%CI: 0.178, -0.305 $\hat{\beta}$=0.279; 95%CI: 0.206, -0.339) and covert control ($\hat{\beta}$=0.187; 95%CI: 0.122, 0.261 and $\hat{\beta}$=0.185; 95%CI: 0.113, -0.257).

At 4 and 7 years of age, mothers who thought their child should weigh more reported higher levels of pressure to eat ($\hat{\beta}$=0.340; 95%CI 0.253, 0.426 and $\hat{\beta}$=0.413; 95%CI: 0.319, 0.506 respectively) compared to mothers who were satisfied with their child's body weight. On the other hand, mothers who thought their child should weigh less reported lower use of pressure to eat ($\hat{\beta}$=-0.320; 95%CI -0.465, -0.174 and $\hat{\beta}$=-0.243; 95%CI: -0.366, -0.121) and monitoring ($\hat{\beta}$=-0.142; 95%CI -0.269, -0.015 and $\hat{\beta}$=-0.104; 95%CI: -0.192, -0.015) also at both ages.

DISCUSSION

Our results suggest that maternal perceived weight, concern for excess weight gain and dissatisfaction with child weight all influenced feeding practices, and that these

associations differed significantly according to type of feeding behavior and child age. Secondly, it suggests moderate stability of perceptions, concerns, and dissatisfaction with child weight over time, and a clear maternal underestimation of child overweight.

In this study, most mothers rated their child as having a normal weight, including mothers of children with overweight or obesity. However, the underestimation of weight was lower by age 7. Parental misperception of child weight has been extensively reported; a meta-analysis found that a large proportion of parents underestimated the weight of their overweight/obese children with more accurate ratings over time (41). There are many reasons for misperception of child weight status. For instance, parents can be reluctant to label their child as overweight because of social pressure to maintain a lower weight and the stigma attached to obesity. Another possible explanation is that with increasing rates in childhood obesity, an upward shift in weight norms has occurred (42). Although the underestimation of child weight status was very high, a higher number (almost 80%) of the mothers were concerned about child weight gain in future, which is consistent with prior research (13,19,43,44). This suggests that whilst mothers may not identify their child as overweight/obese they are nonetheless aware of the consequences of excess weight gain and express concern about this. Additionally, most mothers were satisfied with their child's body weight, which corroborates previous literature (45).

At both ages, mothers tended to report more frequent use of pressure to eat when they perceived their child as having underweight or considered that the child should weigh more. In contrast, those who perceived their child as having overweight or who believed their child should weigh less reported lower levels of pressuring practices. Associations between weight perception and this feeding practice have been widely reported (17,19,26,27). However, dissatisfaction with child body weight has seldom been addressed. Taken together, these findings show that maternal pressuring might arise because of the mother's perception of the child as thin and the desire for a heavier child. Mothers might consider that a lower weight, which may be a biological characteristic of the child, could compromise their healthy development and growth (46), using pressuring practices to prevent this. However, it is important to note that pressure to eat could be also used in response to displaying food-avoidant eating behaviors such as food fussiness or picky eating (47). Pressure to eat refers to the parents' insistence or demands that

their children eat more food, using such strategies as insisting that children clean their plates and providing repeated prompts to eat (48). However, parents' intentions may be counterproductive, for example, leading to lower fruit and vegetable intake (6) and associated with low weight status (10), and probably reducing the willingness to consume the food pressured to eat (49).

Apart from pressure to eat, associations between maternal weight perception and feeding practices were different at 4 and 7 years of age. In older children, coincident with more accurate weight perception, a higher number of significant associations were observed. Mothers who perceived their child as having underweight restricted less the child's access to foods. This agrees with the association reported for pressuring practices, suggesting that mothers are reactive to their child's low weight and use specific feeding strategies to promote food intake. At 7 years of age, mothers who perceived their child as having overweight reported lower levels of monitoring, compared to mothers who perceived their children as having a normal weight. In previous studies, with smaller samples (n= 210 and n=186), no associations were found between perceived weight status and monitoring (19,26). A study from our cohort (from 4 to 7 years of age) also concluded that children's BMI did not predict monitoring (10). Other studies described comparable results, with parents reporting similar levels of monitoring of children across different weight status (50). The monitoring subscale measures how much the mother keeps track of the number of sweets, snacks, and high-fat food her child eats (34), and may reflect the food environment the mother shares with the child and is not a direct response to child weight. In line with this, it was found that mothers who believed their child should weigh less reported lower levels of this feeding practice. Although overweight perception and the desire for a thinner child were inversely associated with monitoring, it is not likely that these cognitions lead mothers to monitor their child's eating less. Thus, maternal monitoring may be employed to maintain a healthy diet and what is perceived as a healthy weight rather than a response to their child weight.

Mothers who perceived their child as having overweight also reported comparatively lower levels of overt control, which is defined as a practice to control food intake that can be detected by the child, such as prohibiting certain foods (35). Studies evaluating overt control with weight perception are lacking. However, a study from Generation XXI found

that actual BMI also did not influence this feeding practice (10). Previous evidence indicates that overt control is associated with monitoring, including in our cohort of children (34,51). Thus, it is not surprising that similar associations were observed for these two domains. In contrast, covert control, which refers to the same restriction, but in a way that cannot be detected by the child (35), was reported more by mothers who perceived their children as overweight.

As expected, maternal concern with their child becoming overweight was associated with more controlling feeding practices at both ages, namely higher restriction and covert control, practices used by parents in an attempt to limit the child's access to "unhealthy" food and to control food intake(48). Concern about child weight gain has been consistently related to restriction (13,19,20,22); however, covert control has been less studied (20).

Our results also showed moderate stability of maternal perception, concern and dissatisfaction about child weight from 4 to 7 years of age. Both maternal and child factors can influence maternal cognitions. Regarding child-related factors, from early to middle childhood children experience considerable development and growth, such as the adiposity rebound, which occurs around 6 years of age (52) and increasing autonomy in food intake. Simultaneously, at age 7 children start primary school and the comparison with their peers might also alter maternal perceptions.

Some strengths and limitations of the present study should be considered. An obvious strength includes the use of a large population-based sample and standardized assessments of maternal feeding practices and maternal cognitions about child weight. Further, our study assessed overt and covert control, which has rarely been addressed to date. Additionally, many previous studies have not adjusted for the child BMI, which conflates the impacts of cognitions with those of the actual weight status (13,20,26,27). However, the study's main limitation is the self-reported nature of both the maternal cognitions and feeding practices. Self-report is known to introduce some measurement error, with mothers potentially misreporting due to lack of awareness, social desirability bias, or because of inherent subjectivity. Studies comparing maternal self-reported feeding practices with independent observations of their feeding have found poor

associations between the two measures (53,54). Nevertheless, the CFQ has been widely used and was previously validated in our sample (10).

In summary, the current research contributes to our understanding of the underlying factors influencing feeding practices. The findings suggest that, in preschool and school-age children, mother's perception of a child as underweight and dissatisfaction with this condition are related to feeding practices promoting food intake. However, mothers who perceived their child as having overweight did not apply more controlling feeding practices to influence their child's food intake. Also, maternal concerns about child future weight gain are associated with feeding strategies to limit and control access to food. Additionally, it was found a moderate stability of maternal cognitions about child weight from 4 to 7 years of age. Despite that, some level of disagreement was found, with mothers being more accurate in identifying overweight/obesity over time. Clearly, it is important to evaluate maternal cognitions related to child weight, since perception, concern and dissatisfaction may be significant drivers of feeding practice independent of actual weight status.

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TABLE 1 Mothers` and child`s characteristics at the 4 years and 7 years follow-up (n=3233).

Maternal characteristics		
Age at baseline, mean (SD)	29.9 (5.0)	
Education at baseline, mean (SD)	11.8 (4.2)	
BMI (kg/m^2) at 4y, mean (SD)	26.3 (4.5)	
Country of birth, n (%)		
Portugal	2933 (90.9)	
Other countries	300 (8.1)	
Household income, n (%)		
>1000 €/month	772 (23.9)	
1001-1500	906 (28.0)	
1501-2000	682 (21.1)	
>2000	872 (27.0)	
Maternal Feeding Practices, mean (SD)	4y	7y
Monitoring	4.2 (0.8)	4.2 (0.7)
Pressure to eat	3.7 (1.0)	3.6 (1.0)
Restriction	4.3 (0.6)	4.3 (0.8)
Overt Control	4.1 (0.6)	4.2 (0.7)
Covert Control	3.2 (0.8)	3.1 (0.8)
Child characteristics		
Sex, n (%)		
Girls	1575 (48.7)	
Boys	1658 (51.3)	
Birth weight, (g), mean (SD)	3187.8 (479.4)	
BMI category, n (%) [b]	4y	7y
Underweight	10 (0.3)	16 (0.5)
Normal weight	2205 (68.2)	2080 (64.3)
Overweight	715 (22.1)	687 (21.2)
Obese	303 (9.4)	450 (13.9)

BMI: body mass index; zBMI: body mass index z-score; y: years old; SD: standard deviation. [a] Counts only total n=2914, due to missing values at 7 years of age. [b] Child weight status was classified according to the WHO criteria (39).

TABLE 2 Maternal perception, concern and dissatisfaction with child weight (n=3233).

	4y	7y	Stability [a]	Non-agreement at 4 and 7y	
Concern about child weight gain	n (%)	n (%)	kappa	n (%)	p-value[b]
Not concerned	636 (19.7)	739 (22.9)	**0.475**	559 (17.3)	0.001
Concerned	2597 (80.3)	2494 (77.1)			
Dissatisfaction with child body weight					
Should weigh more	592 (18.3)	710 (24.4)	**0.346**	932 (28.8)	0.001
Should weigh less	213 (6.6)	436 (15.0)			
About right	2422 (74.9)	1768 (60.7)			
Maternal Perception of weight					
Underweight	249 (7.7)	264 (8.2)	**0.404**	555 (17.2)	0.001
Normal weight	2813 (87.0)	2599 (80.4)			
Overweight	171 (5.3)	370 (11.4)			

[a] The values represent kappa coefficients. [b] McNemar McNemar's or Bowker's Test to test if the answers change significantly from 4 to 7 years of age. Statistically significant results are shown in bold type (p<0.001).

TABLE 3 Associations between maternal perception, concern and dissatisfaction with child weight and maternal feeding practices at 4 years old (n=3233).

		Maternal feeding practices at 4y				
		Monitoring	Pressure to eat	Restriction	Overt control	Covert control
		β̂ (95% CI)	β̂ (95% CI)	β̂ (95% CI)	β̂ (95% CI)	β̂ (95% CI)
Maternal perception of child weight at 4y						
Normal weight		(ref)	(ref)	(ref)	(ref)	(ref)
	M1 [a]	0.062 (-0.038, 0.162)	**0.514 (0.394, 0.634)**	**-0.208 (-0.300, -0.116)**	-0.038 (-0.112 ,0.035)	**-0.112 (-0.221, -0.003)**
Underweight	M2	0.042 (-0.064, 0.147)	**0.364 (0.243, 0.486)**	**-0.207 (-0.0304, -0.110)**	-0.034 (-0.111, 0.043)	-0.065 (-0.176, 0.049)
	M1	**-0.122 (-0.241, -0.003)**	**-0.714 (-0.857, -0.570)**	0.071 (-0.039, 0.180)	-0.067 (-0.154, 0.021)	**0.134 (0.004, 0.263)**
Overweight	M2	-0.092 (-0.228, 0.045)	**-0.333 (-0.490, -0.177)**	0.067 (-0.058, 0.019)	-0.049 (-0.149, 0.050)	0.021 (-0.126, 0.169)
Maternal concern about child weight gain at 4y						
Not concerned		(ref)	(ref)	(ref)	(ref)	(ref)
	M1	-0.040 (-0.107, 0.027)	**-0.180 (-0.262, -0.098)**	**0.241 (0.178, 0.305)**	0.038 (-0.11, 0.087)	**0.203 (0.131, 0.276)**
Concerned	M2	-0.020 (-0.089, 0.049)	-0.064 (-0.144, 0.016)	**0.241 (0.178, 0.305)**	-0.037 (-0.014, 0.087)	**0.187 (0.112, 0.261)**
Maternal child body dissatisfaction at 4y						
About right		(ref)	(ref)	(ref)	(ref)	(ref)
Should weigh more	M1	0.033 (-0.037, 0.102)	**0.502 (0.420, 0.584)**	-0.058 (-0.122, 0.006)	**0.031 (-0.020, 0.082)**	**-0.092 (-0.168, -0.0117)**
	M2	0.031 (-0.045, 0.106)	**0.340 (0.253, 0.426)**	-0.047 (-0.177, 0.022)	0.024 (-0.031, 0.079)	-0.039 (-0.121, 0.043)
Should weigh less	M1	**-0.149 (-0.258, -0.041)**	**-0.627 (-0.755, -0.499)**	0.091 (-0.009, 0.191)	-0.061 (-0.140, 0.018)	**0.131 (0.014, 0.249)**
	M2	**-0.142 (-0.269, -0.015)**	**-0.320 (-0.465, -0.174)**	0.074 (-0.043, 0.190)	-0.059 (-0.151, 0.034)	0.029 (-0.108, 0.166)

CI= confidence interval; y: years of age; ref: reference category. Statistically significant associations are shown in bold type. [a] M1: unadjusted model, M2: model adjusted for maternal education, child sex and zBMI at 4 years of age.

TABLE 4 Associations between maternal perception, concern and dissatisfaction with child weight and maternal feeding practices at 7 years old (n=3233).

		Maternal feeding practices at 7y				
		Monitoring	Pressure to eat	Restriction	Overt control	Covert control
		β̂ (95% CI)	β̂ (95% CI)	β̂ (95% CI)	β̂ (95% CI)	β̂ (95% CI)
Maternal perception of child weight at 7y						
Normal weight		(ref)	(ref)	(ref)	(ref)	(ref)
	M1[a]	0.041 (-0.075, 0.127)	**0.633 (0.506, 0.706)**	**-0.172 (-0.268, -0.076)**	0.049 (-0.022, 0.120)	**-0.108 (-0.211, -0.005)**
Underweight	M2	0.028 (-0.064, 0.121)	**0.329 (0.199, 0.459)**	**-0.114 (-0.217, -0.010)**	0.048 (-0.028, 0.124)	-0.058 (-0.169, 0.052)
	M1	**-0.123 (-0.197, -0.049)**	**-0.775 (-0.885, -0.666)**	**0.113 (0.030, 0.196)**	**-0.087 (-0.148, -0.026)**	**0.363 (0.274, 0.452)**
Overweight	M2	**-0.102 (-0.193, -0.010)**	**-0.272 (-0.401, -0.143)**	0.019 (-0.084, 0.122)	**-0.081 (-0.157, -0.006)**	**0.279 (0.170, 0.389)**
Maternal concern about child weight gain at 7y						
Not concerned		(ref)	(ref)	(ref)	(ref)	(ref)
	M1	-0.043 (-0.098, 0.013)	**-0.248 (-0.334, -0.163)**	**0.299 (0.237, 0.361)**	0.006 (-0.040, 0.053)	**0.235 (0.168, 0.303)**
Concerned	M2	-0.016 (-0.076, 0.044)	0.035 (-0.050, 0.120)	**0.279 (0.206, 0.339)**	0.016 (-0.033, 0.066)	**0.185 (0.113, 0.257)**
Maternal child body dissatisfaction at 7y						
About right		(ref)	(ref)	(ref)	(ref)	(ref)
Should weigh more	M1	**-0.008 (-0.067, 0.052)**	**0.657 (0.572 ,0.743)**	-0.053 (-0.119, 0.014)	**0.041(-0.008, 0.090)**	-0.060 (-0.130, 0.011)
	M2	-0.023 (-0.090, 0.045)	**0.413 (0.319, 0.506)**	-0.011 (-0.086, 0.064)	0.021 (-0.034, 0.076)	-0.001(-0.080, 0.078)
Should weigh less	M1	**-0.128 (-0.200, -0.057)**	**-0.602 (-0.705, -0.500)**	**0.152 (0.072, 0.023)**	**-0.063(-0.121, -0.004)**	**0.325 (0.241, 0.410)**
	M2	**-0.104 (-0.192, -0.015)**	**-0.243 (-0.366, -0.121)**	0.073 (-0.025, 0.172)	-0.050 (-0.122, 0.022)	**0.243 (0.140, 0.347)**

CI= confidence interval; y: years of age; ref: reference category. Statistically significant associations are shown in bold type. [a] M1: unadjusted model, M2: model adjusted for maternal education, child sex and zBMI at 7 years of age.

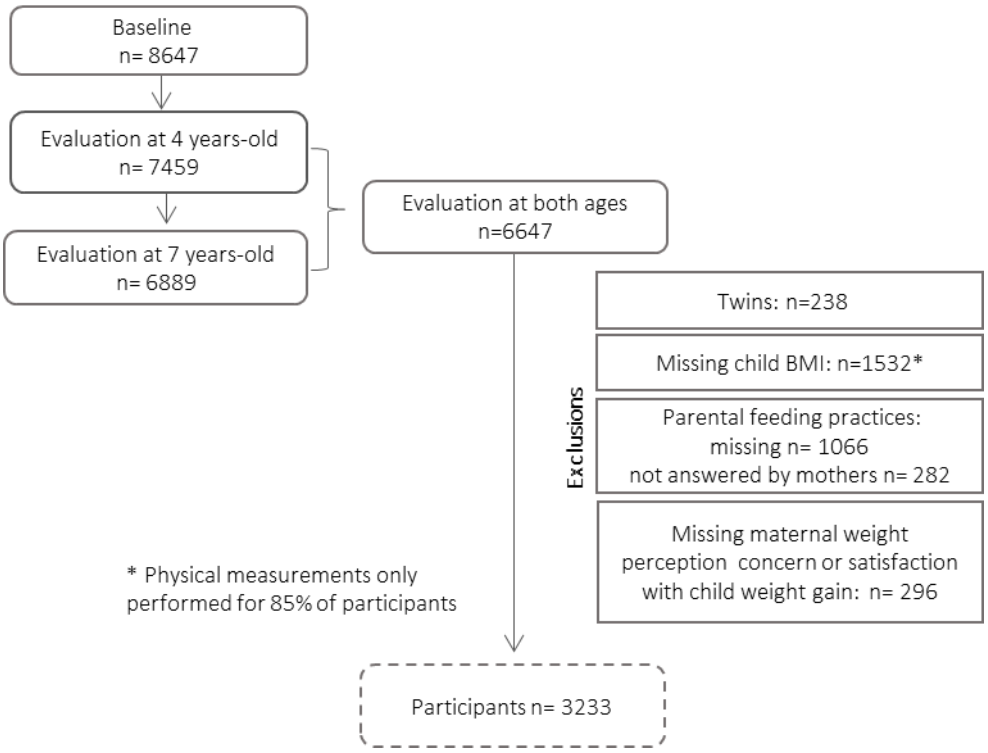

FIGURE 1 Flowchart of participant's selection

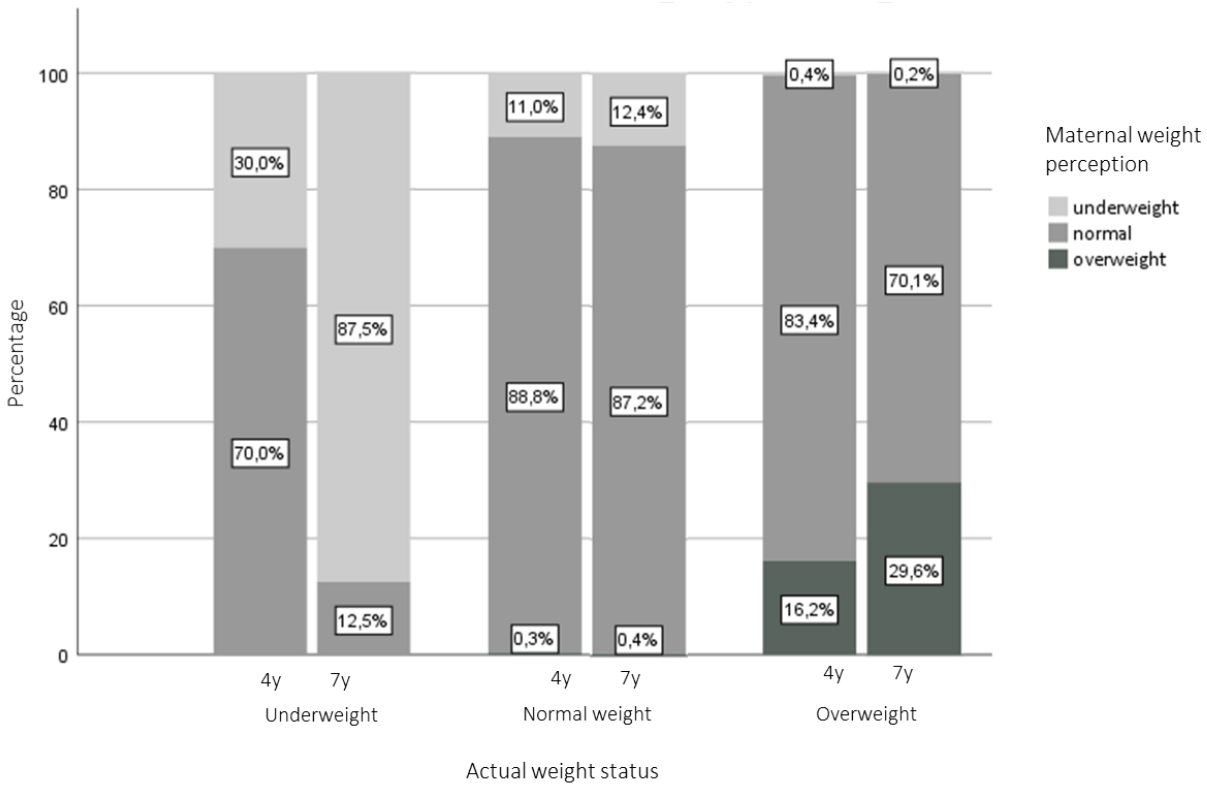

FIGURE 2 Maternal weight perception and actual weight status ate 4 and 7 years of age (n=3233). Child weight status was classified according to the WHO criteria (39)

SUPPLEMENTARY MATERIAL

Supplemental Table 1

Maternal concern and dissatisfaction with child weight by BMI category (n=3233).

	4 years			7 years		
Concern about child weight gain, n (%)	**Underweight**	**Normal weight**	**Overweight**	**Underweight**	**Normal weight**	**Overweight**
Not concerned	4(60.0)	556(25.2)	76(7.5%)	9(56.3)	502(25.2)	125(10.2)
Concerned	6(40.0)	1649(74.8)	942(92.5)	7(43.8)	1494(74.8)	1096(89.8)
Dissatisfaction with child body weight, (n%)						
Should weigh more	6(60.0)	564(25.6)	22(2.2)	16(100.0)	662(36.6)	32(2.9)
Should weigh less	0(0.0)	7(0.3)	206(20.3)	0(0.0)	18(1.0)	418(38.3)
About right	4(40.0)	1630(74.1)	788(77.6)	0(0.0)	1808(62.4)	1090(58.7)

Child weight status was classified according to the WHO criteria (39).

GENERAL DISCUSSION AND MAIN CONCLUSIONS

In this thesis, using data from a large population-based birth cohort, we explored the associations between weight and appetitive behaviours in childhood, as well as the influence of parental feeding practices in the development of these behaviours. We also examined how parental perceptions and concerns about their child's weight affect the feeding practices that they adopt.

The Behavioural Susceptibility Theory was formulated to explain the large variations in weight among individuals, proposing that appetitive behaviours mediate the genetic predisposition to obesity (25,26). Several studies in this area have shown that individuals with higher weight are more responsive to food cues and have less satiety sensitivity than their lean peers (27,74). However, evidence from longitudinal data is limited, making it impossible to determine the cause-effect relationship. Genes may influence adiposity via other processes, and adiposity causes subsequent changes in appetite (88). To address this research gap, we examined the direction and magnitude of the associations between appetitive behaviours and BMI across childhood (from 7 to 10 years of age). We performed a cross-lagged analysis, which allows examining both the degree to which appetitive behaviours predicted changes in children's BMI over time, as well as examine the reverse. It was found that BMI at age 7 predicted appetitive behaviours (Food responsiveness, Enjoyment of food, Emotional overeating, Desire to drink, Satiety responsiveness, Slowness in eating, and Food fussiness) three years later, rather than the opposite. These results suggest that, at this timeframe, BMI precedes the development of appetitive behaviours; therefore, a higher BMI in middle childhood might increase the risk of developing an avid appetite over the years. Several biological mechanisms, such as hormones and neurotransmitters involved in food intake regulation, may potentially explain this. For instance, leptin resistance and reduced availability of dopamine receptors in individuals with overweight or obesity may promote food consumption, which may lead to weight gain (166,167).

Studies that have used a comparable analytic approach, found similar associations from 4 to 10-years-old (84) and from 4 to 8-years old (85); however, in infants from 3 to 15 months associations from appetite to weight were stronger than the reverse, which contradict our results (86), suggesting that the direction of influence may change depending on the developmental stage (i.e. the effect in infancy might differ from the

effect in childhood and adulthood) (88). The strongest influence of appetite on weight may take place in early life. Indeed, a study comparing the weight gain in twins with discordant appetite profiles showed that those with higher Food responsiveness and those with lower Satiety responsiveness at age 3 months grew faster than their sibling (weight trajectories differed significantly resulting in weight differences close to 1 kg by 15 months) (168). These findings are particularly relevant since this study has a powerful design able to rule out potential family confounding (twins grow up in the same environment), providing convincing evidence for a causal role for appetite in weight gain infancy (168) and highlighting the relevance of further research in this field. Several points need to be clarified, such as the development and stability of appetite over the lifespan. Longitudinal studies of genetic risk, adiposity, and appetite are required to elucidate the direction of associations and timing of expression, namely during childhood.

Infants are born with an ability to self-regulate their food intake, which appears to decrease with age (169). Some authors proposed that nonresponsive feeding practices may disrupt this inherent ability, contributing to the development of obesogenic eating behaviours (55,78), and therefore to weight gain (118). However, evidence supporting this hypothesis is limited (over-reliance on cross-sectional designs, often with small samples, and most studies did not evaluate the dynamic nature of parents–children feeding interactions). Using a cross-lagged modelling approach, our study explored the bidirectional associations between children's eating behaviours (eating large amounts of food, eating slowly and food refusal) and parental feeding practices (Perceived Monitoring, Restriction, and Pressure to eat) from 4 to 7 years of age. We found that in children who eat large amount of food at 4 years of age parents reported a higher level of Restriction three years later. Apart from this result, all associations had a bidirectional effect of similar magnitude; thus, parents adapt their feeding practices in response to their children's eating behaviours, but these behaviours are also reactive to parental feeding practices. These results indicate that parents and children reciprocally influence each other over time. For instance, when a child is refusing to eat parents pressure the child to eat more. Despite their best intentions, this practice may be counterproductive reducing the willingness to consume the pressured foods, and consequently, worsening food refusal (170). Most previous studies, using cross-lagged models, have found that

parents and children mutually influence each other in the context of feeding (84,145,147). However, the extent to which parental feeding practice or children's behaviour can be considered the key driver of this bidirectional relationship likely depends on the domains being measured and children's age, which makes it difficult to draw general conclusions.

Evidence from a randomized controlled trial shows that giving parents anticipatory guidance on positive feeding practices may result in improved appetite regulation in younger children (171). Modifying maternal feeding practices lead to small but significant changes in children's eating behaviour, particularly Satiety and Food responsiveness three years after the intervention (171). Taken together, these findings emphasize that parents need to be provided with alternative feeding practices and strategies to understand and respond appropriately to their children's individual eating behaviours.

To tailor specific interventions to guide parents is essential to fully understand the underlying factors of their feeding practices. Besides children's eating behaviours, parents' perceptions and concerns about children's weight status appear to play a pivotal role (154,157,158,172). There is considerable research on this topic, but most studies were performed in small samples and have not tested how parental cognitions change across childhood. Additionally, many of them did not consider the child BMI as a confounder which conflates the impacts of cognitions with those of the actual weight status. To overcome this flaw, we examined the association between maternal perception, concern and dissatisfaction with child's weight and maternal feeding practices at two-time points (at 4- and 7 years of age). Our results reveal that underestimation of weight is high in mothers whose children have overweight or obesity (84% at 4 and 70 % at 7 years). In general, mothers are satisfied with the bodyweight of their children (75% at age 7 and 51% at age 7) but concerned about their children becoming overweight (about 80%). There was some agreement between maternal cognitions at both ages, but weight perception was more accurate at 7-years-old. Maternal perceived weight, concern for excess weight gain and dissatisfaction with child's weight all influence feeding practices, but these associations differ significantly according to the feeding practice and are stronger and consistent in older ages. Practices to promote food intake seem to arise when a mother perceive their child as underweight

and consider that the child should weigh less; while practices used to restrict access to food are applied in response to mother's concern about child's future weight gain. Overall, mothers want their children to have what they perceive as a healthy weight using specific feeding practices to accomplish that. For example, when a mother believes that the lower weight of their child could compromise their growth and development tend to use pressuring practices trying to promote weight gain. Cognitions about child weight appear to be significant drivers of feeding practices independent of actual weight status; therefore, they should be considered when designing an intervention to guide mothers and main caregivers in the feeding process.

This work has several strengths and limitations that warrant discussion. A major strength is that the children were part of a large population-based cohort regularly followed since birth into late childhood using the same measures over the years. This allowed to evaluate bidirectional relationships between variables and stability across time, and several potential confounding factors were assessed, overcoming some limitations of most previous studies. There are also several limitations to consider. The major limitation is the self-reported nature of the measures of parental and children's behaviours. Although self-reporting is the most practical way to assess behaviours in a large-scale study, studies comparing self-reported parental feeding practices with independent observations have found poor associations between the two measures (173,174). On the other hand, reports of children's eating behaviours have shown to be a reliable reflection of independent observations (175,176). In the current studies, we have used tools that were previously tested - CEBQ and CFQ and Overt/Covert Control scale - and have shown good internal consistency and reliability in this population (177,178); nonetheless, we acknowledge that it may be subject to information biases. It should be noted that we mostly evaluated maternal feeding , and it has been suggested that mothers and fathers use different feeding strategies (179). Studies evaluating the fathers' role are extremely limited and might give relevant information into the feeding practices within the family context (119).

In conclusion, we found that from 7 to 10 years of age appetitive behaviours did not predict weight gain, instead, these behaviours were reactive to children's BMI, which suggests that weight might affect appetite regulation in middle childhood. To clarify this,

it is important to perform longitudinal studies covering birth to adolescence. Future research should aim to understand the underlying mechanism, and which factors are involved in regulating appetite at different developmental stages.

Our results also highlight that parental feeding practices might shape children's eating behaviours (eating large amounts, eating slowly and food refusal), but this influence is bidirectional, as parents use specific feeding practices in response to children's characteristic and their perceptions and beliefs. Our results support that the perception of a child as underweight, dissatisfaction with child weight, and concerns about future weight gain are associated with feeding practices. Thus, parents and children reciprocally influence each other's behaviours in the context of feeding. Longitudinal studies examining parental feeding practices in a more naturalistic manner (e.g., observational studies) are necessary to address the inherent bias of self- reported measures. Experimental and interventional studies are warranted to examine the cause and effect of parental feeding and child-outcomes and to evaluate which interventions are the best in promoting healthy child development.

Overall, considering the current evidence, parents should focus not only on children's characteristics but on creating a structured environment (such as the consistent and repeated offering of healthy foods to children) that naturally limits unwanted behaviours without requiring excessive control. Responsive feeding practices that respect the children's hunger and fullness cues should be privileged. It is important to bear in mind that children's individual differences influence the feeding-eating relationship and may place challenges for parents in promoting healthy behaviours. Therefore, to educate parents in which are the best strategies to use, it is essential to consider both parents' and children's characteristics and their family dynamics.

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