

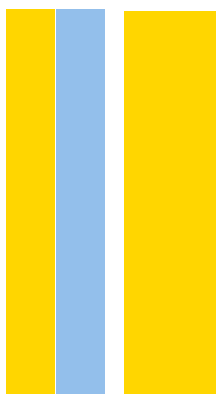
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Healthy Eating Pattern in Childhood: Tracking and its Related Factors

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2019



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Healthy Eating Pattern in Childhood: Tracking and its Related Factors

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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Porto, 2019

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

A sua concretização 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 e pela Administração Regional de Saúde Norte, pela Fundação Calouste Gulbenkian, pelo FEDER, inserido no Programa Operacional Fatores de Competitividade (COMPETE), e por fundos nacionais da Fundação para a Ciência e a Tecnologia (FCT). Em particular, os objetivos científicos desta tese inserem-se nos projetos de investigação PTDC/SAU-EPI/ 121532/2010 (FCOMP-01-0124-FEDER-021177), “Appetite and obesity: Regulação do apetite e obesidade infantil: uma abordagem para compreender as influências genéticas e comportamentais” (POCI-01-0145-FEDER-030334) “Appetite and adiposity - evidence for gene-environment interplay in children” (IF/01350/2015), e bolsa de doutoramento FCT SFRH/BD/92389/2013. Recebeu ainda apoio da EPIUnit (UID-DTP/04750/2013).

A presente dissertação tem por base dois manuscritos, nos quais colaborei ativamente na definição e operacionalização das hipóteses testadas, na análise e interpretação dos dados e fui ainda responsável pela redação das suas primeiras versões:

I. Adherence to a healthy eating index from pre-school to school age and its associations with sociodemographic and early life factors.

II. Bidirectional relationship between children's appetitive behaviours and diet quality from 7 to 10 years: a prospective cohort study.

Agradecimentos

À minha orientadora Sofia Vilela, por me ter apoiado desde o início, por todo o carinho e compreensão. Obrigada por se disponibilizar para me ajudar na realização deste trabalho e por ter acreditado em mim.

À Professora Doutora Carla Lopes, pela oportunidade e privilégio de trabalhar consigo e pelos constantes ensinamentos, que contribuem muito para o enriquecimento da minha formação académica.

Ao Professor Milton Severo, pela disponibilidade e ajuda com a análise estatística.

Ao Professor Doutor Henrique Barros, por gentilmente ter disponibilizado a informação recolhida no âmbito da coorte de nascimento Geração XXI.

À Cátia Ferreira, e a toda a equipa Geração XXI, pessoas excecionais que sempre se disponibilizaram para me ajudar. Obrigada por tudo aquilo me ensinaram, pela amizade e por me fazerem sentir tão confortável no departamento.

Aos meus colegas do mestrado, especialmente à Joana, Cláudia, Catarina, Tiago, César e Pedro, pelo apoio total, pela partilha de experiências tão enriquecedoras e pela amizade que nos une.

Aos meus pais, expresso o meu profundo agradecimento por nunca terem duvidado das minhas capacidades e me apoiarem incondicionalmente em todas as minhas decisões. Sem eles nunca teria chegado até aqui. Espero que esta etapa que termina possa retribuir todo o apoio e dedicação que sempre me ofereceram. A eles, dedico todo este trabalho.

Às minhas irmãs, ao meu cunhado e aos meus sobrinhos, obrigada por acreditarem sempre em mim e naquilo que faço, por constantemente mostrarem que se orgulham de mim.

Ao Ricardo, um agradecimento especial por todo o apoio incondicional e carinho diário, pelas palavras doces nos momentos mais amargos, pela transmissão de confiança e motivação constantes, por nunca me deixar desistir e baixar os braços. Por tudo, a minha enorme gratidão!

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List of Abbreviations

BEBQ – Baby Eating Behaviour Questionnaire

BMI – Body Mass Index

CEBQ – Children’s Eating Behaviour Questionnaire

CFI – Comparative Fit Index

DEBQ – Dutch Eating Behaviour Questionnaire

FFQ – Food Frequency Questionnaire

HEI – Healthy Eating Index

SSB – Sugar Sweetened Beverages

WHO – World Health Organization

Resumo

Contextualização

Nas últimas décadas, várias mudanças têm ocorrido na dieta da população. Em particular, as crianças são mais vulneráveis a uma exposição excessiva de escolhas alimentares não saudáveis, o que contribuiu para um aumento nos valores de prevalência de excesso de peso. A infância é um período importante para o desenvolvimento de hábitos e comportamentos alimentares que podem ter um impacto relevante na saúde no imediato e persistir na idade adulta. Compreender a estabilidade dos hábitos e comportamentos alimentares das crianças no início da vida, permite a criação de estratégias e intervenções, bem como a definição de momentos-chave para intervir, para obtenção de melhores resultados em saúde, e, principalmente, reduzir a incidência da obesidade. Os hábitos e comportamentos alimentares podem surgir como resultado de uma combinação de vários fatores, principalmente devido a fatores biológicos, ambientais, sociais e genéticos. Além disso, a consideração de diferentes abordagens, como a abordagem *a priori*, através do desenvolvimento de um índice para avaliar qualidade alimentar, a sua estabilidade e suas influências ao longo da infância, é escassa na literatura.

Objetivos

Esta tese tem como objetivo avaliar a estabilidade/manutenção da qualidade alimentar na infância, assim como os fatores relacionados com esta estabilidade e a sua associação com comportamentos alimentares relacionados com o apetite. Para responder a esse objetivo principal, dois objetivos específicos foram formulados, resultando em dois manuscritos:

1. Avaliar a estabilidade/manutenção do consumo alimentar e da qualidade alimentar das crianças entre os 4 e os 7 anos, e a influência de fatores do início da vida e das características sociodemográficas;
2. Avaliar as associações bidirecionais entre a qualidade alimentar e os comportamentos alimentares associados com o apetite dos 7 para os 10 anos.

Métodos

Esta tese inclui dados obtidos no âmbito da coorte Geração XXI, uma coorte de nascimento prospetiva de base populacional. Os participantes foram recrutados entre 2005 e 2006 em 5 unidades de maternidade públicas da área do Porto, Portugal. Após o parto, as mães foram convidadas a participar no estudo. Das mães convidadas, 91,4% aceitaram participar (n=8495 mães e n=8647 crianças). Aos 4 anos de idade foi realizado o primeiro

follow-up da coorte total (86% de participação), aos 7 anos foi realizado o segundo follow-up (80% de participação) e aos 10 anos foi realizado o terceiro follow-up (76% de participação).

Em todos os follow-ups as informações foram recolhidas por entrevistadores treinados, através de questionários estruturados. Os questionários incluíram informação sobre características sociodemográficas, estado de saúde e estilo de vida da criança. Foram ainda efetuadas medições antropométricas das crianças e das suas mães por entrevistadores treinados, através de procedimentos padronizados. O consumo alimentar das crianças foi avaliado através de um Questionário de Frequência Alimentar (QFA) validado, referente aos 6 meses anteriores à entrevista, e por diários alimentares de 3 dias. Nas avaliações realizadas aos 7 e aos 10 anos, as mães preencheram o ainda o *Questionário de Comportamento Alimentar da Criança* (CEBQ), um instrumento psicométrico de reporte dos pais previamente validado em Portugal.

Através da informação recolhida pelo QFA, foi construído um índice de alimentação saudável aos 4, 7 e 10 anos, para avaliar a adesão a recomendações alimentares da Organização Mundial de Saúde e para avaliar a qualidade alimentar na infância. Foram criados quartis de frequência de consumo para oito grupos alimentares, atribuindo uma pontuação entre 1 e 4 pontos. Para os alimentos considerados mais saudáveis, o maior quartil de consumo foi pontuado com 4 pontos e o menor com 1 ponto. Para os alimentos considerados menos saudáveis, a pontuação foi atribuída de forma inversa. A pontuação final varia entre 8 e 32 pontos, e quanto maior a pontuação maior a qualidade alimentar.

No artigo I as associações entre a pontuação do índice de alimentação saudável aos quatro anos, fatores do início da vida e características sociodemográficas, e o índice de alimentação saudável aos sete anos, foram avaliados através de modelos de regressão linear [coeficientes de regressão (β) e respetivo intervalo de confiança a 95% (IC95%)].

No artigo II as associações entre a qualidade alimentar e os comportamentos alimentares relacionados com o apetite dos 7 para os 10 anos, foram avaliados através de modelos de regressão linear (β e IC95%). Para avaliar a direção da associação entre a qualidade alimentar e os comportamentos alimentares relacionados com o apetite dos 7 para os 10 anos, foi realizada uma análise *cross-lagged* ajustada para potenciais confundidores.

Resultados

Artigo I

O índice de alimentação saudável teve uma pontuação média de 21,4 (intervalo: 12 a 31) aos 4 anos e 20,3 (intervalo: 11 a 31) aos 7 anos. Após ajuste para potenciais confundidores, foi encontrada uma associação positiva entre o índice de alimentação

saudável aos 4 e aos 7 anos ($\beta = 0,384$, IC 95%: 0,356; 0,441). Os anos de escolaridade ($\beta = 0,094$, IC 95%: 0,071; 0,116) da mãe e a qualidade da sua alimentação ($\beta = 0,182$, IC 95%: 0,155; 0,209) associaram-se positivamente com a qualidade alimentar aos 7 anos. Não foram encontradas associações entre os fatores do início de vida (por exemplo, características da gravidez) e a qualidade alimentar das crianças.

Artigo II

Aos 10 anos de idade, as crianças obtiveram uma pontuação média no índice de alimentação saudável de 18,6 (intervalo: 10 a 30. Após ajuste para potenciais confundidores, foi encontrada uma associação bidirecional entre a seletividade e a qualidade alimentar ($\beta_{\text{padronizado}} = -0,033$ e $\beta_{\text{padronizado}} = -0,030$, $p < 0,001$). Uma associação unidirecional foi encontrada entre uma melhor qualidade alimentar aos 7 anos e menor resposta à saciedade aos 10 anos ($\beta_{\text{padronizado}} = -0,039$, $p < 0,001$), e entre um maior prazer em comer aos 7 anos e melhor qualidade alimentar aos 10 anos ($\beta_{\text{padronizado}} = 0,046$, $p < 0,001$).

Conclusões

Foi observado algum nível de estabilidade da qualidade alimentar aos 4, 7 e 10 anos, ou seja, quanto melhor for a qualidade alimentar no início da vida, melhor será em idades mais avançadas. Fatores sociodemográficos e o comportamento materno influenciam a qualidade alimentar, especialmente a educação e a dieta materna. Foi encontrada uma associação bidirecional inversa entre a qualidade alimentar das crianças e a seletividade, e uma maior qualidade da alimentar aos 7 anos de idade foi associada à menor resposta à saciedade alguns anos depois. Além disso, crianças com maior prazer em comer aos 7 anos de idade são aquelas com maior qualidade de dieta aos 10 anos de idade. Intervenções precoces que envolvam mães menos escolarizadas e com pior qualidade alimentar são muito importantes, pois os hábitos e comportamentos alimentares são definidos no início da infância e tendem a persistir na idade adulta.

Palavras-chave: Appetite, CEBQ, comportamento alimentar, estabilidade/manutenção, estudo de coorte, índice de alimentação saudável, painel de design *cross-lagged*, qualidade alimentar;

Abstract

Background

In recent decades, several changes have occurred in the population's diet. In particular, children are more vulnerable to an excessive exposure to unhealthy food choices, which have contributed to an increase in overweight prevalence values. Childhood is an important period for the development of eating habits and behaviours that can have a relevant impact on immediate health and persist into adulthood. Understanding the stability of children's eating habits and behaviours early in life allows the creation of strategies and interventions, as well as the definition of key moments to intervene to improve health outcomes, and especially to reduce the incidence of obesity. Eating habits and behaviours may arise as a result of a combination of several factors, mainly due to biological, environmental and social, and genetic factors. Also, the consideration of different approaches, such as a *a priori* approach, by creating an index to characterize and track children's diet quality and its influences throughout childhood is scarce in the literature.

Aims

This thesis aims to evaluate the tracking of diet quality in childhood, related factors and its association with appetitive behaviours. To answer this main objective, two specific objectives were formulated, resulting in two manuscripts:

1. To evaluate the tracking of food consumption and diet quality from 4 to 7 years of age, and the influence of early life and sociodemographic characteristics;
2. To assess the bidirectional associations between children's diet quality and appetitive behaviours from 7 to 10 years of age.

Methods

This thesis includes data obtained from the Generation XXI cohort, a prospective population-based birth cohort. Participants were recruited between 2005 and 2006 from 5 public maternity units in the Porto area, Portugal. After delivery, the mothers were invited to participate in the study. Of the invited mothers, 91.4% agreed to participate (n = 8495 mothers and n = 8647 children). At 4 years of age the first follow-up of the total cohort was performed (86% of participation), at 7 years of age the second follow-up (80% of participation) and at 10 years of age the third follow-up (76% of participation) occurred. In all follow-ups, the information was collected by trained interviewers through structured

questionnaires. Questionnaires included information on the child's sociodemographic characteristics, health status and lifestyle. Objectively anthropometric measurements of the children and their mothers were also performed, by trained interviewers using standardized procedures. Children's food intake was assessed by a validated Food Frequency Questionnaire (FFQ), referring to the 6 months prior to the interview, and by 3-day food diaries. In the evaluations performed at 7 and 10 years, the mothers completed the Children Eating Behaviour Questionnaire (CEBQ), a parental report psychometric instrument previously validated in Portugal.

Based on the information gathered by the FFQ, a healthy eating index at 4, 7 and 10 years was developed to assess adherence to World Health Organization food recommendations for children and overall food quality. Quartiles of consumption frequency were created for eight food groups, giving a score between 1 and 4 points. For foods considered healthy, the highest quartile of consumption was scored with 4 points and the lowest with 1 point. For foods considered to be less healthy, the score was inversely assigned. The final score ranges between 8 and 32 points, and the higher the score the higher the food quality.

In the paper I, the associations between the 4-year healthy eating index score, early life factors and sociodemographic characteristics, and the 7-year healthy eating index were assessed using linear regression models [regression coefficients (β) and respective 95% confidence intervals (95%CI)].

In paper II, associations between diet quality and appetitive behaviours from 7 to 10 years were assessed using linear regression models (β and 95%CI). To assess the direction of the association between diet quality and appetitive behaviours from 7 to 10 years, a cross-lagged analysis adjusted for potential confounders was performed.

Results

Paper I

The healthy eating index had an average score of 21.4 (range: 12 to 32) at 4 years old and 20.3 (range: 11 to 31) at 7 years old. After adjustment for potential confounders, a positive association was found between the healthy eating index at 4 and 7 years ($\beta=0.384$, 95%CI: 0.356, 0.441). Maternal years of education ($\beta=0.094$, 95%CI: 0.071, 0.116) and maternal dietary score ($\beta=0.182$, 95%CI: 0.155, 0.209) were positively associated with children's dietary quality. No associations were found between early life factors (e.g. pregnancy characteristics) and children's diet quality.

Paper II

At 10 years of age, children had an average score on the healthy eating index of 18.6 (range: 10 to 30). After adjustment for potential confounders, a bidirectional association was found between the food fussiness and diet quality ($\beta_{\text{standardized}}=-0.033$ and $\beta_{\text{standardized}}=-0.030$, $p<0.001$). A unidirectional association was found between a better diet quality at 7 years of age and lower satiety responsiveness at 10 years ($\beta_{\text{standardized}}=-0.039$, $p<0.001$), and between higher enjoyment of food at 7 years and better diet quality at 10 years ($\beta_{\text{standardized}}=0.046$, $p<0.001$).

Conclusions

We observed some level of tracking of diet quality at 4, 7 and 10 years, that is, the better the quality of diet early in life, the better will be at older ages. Sociodemographic factors and maternal behaviour influence diet quality, especially maternal education and maternal diet. A bidirectional inverse association was found between children's diet quality and food fussiness and a higher diet quality at 7 years of age were associated with lower satiety responsiveness a few years later. Moreover, children having higher enjoyment of food at 7 years of age were the ones with a higher diet quality at 10 years of age. Early interventions involving less educated and poorer diet quality mothers are very important, as eating habits and behaviours are defined early in childhood and tend to persist into adulthood.

Keywords: Appetite, CEBQ, cohort studies, Cross-lagged panel design, diet quality, eating behaviours, Healthy eating index, tracking

Introduction

Children's eating habits: the influence on the development of obesity

In the last few decades, major changes have occurred regarding the family environment and overall diet of the population. In the past, due to the poverty conditions, family life was devoted to growing their food, mostly poor in nutrients and energy, and without any protection against potentially toxic substances (1). Currently, we are facing a very different family scenario. Since in most families both parents work, time availability is very limited and an increase in the number of meals eaten away from home has increased significantly. The food industry has responded to these family needs, and in general eating habits have been developed in unprecedented environments of such abundance and food availability, with ready-to-eat foods, large portions, energy-dense and inexpensive foods (1).

Recognition of the benefits of healthy eating has been largely lost as a result of globalization and the development of international food markets (2). An increase in the food marketing and an ongoing technological advances that reduce the need for physical work has translated into a poorer diet, with impact in the rise of chronic diseases in epidemiological proportions such as obesity, diabetes, heart disease and cancer (3). Still, the risk of developing these conditions may be reduced with the establishment of good eating practices and healthy lifestyles, from the early years of life (4).

Childhood is characterized by being a period of growth and constant physical change, critical for the development of healthy lifestyles, including eating habits and practice of physical activity (5). It is during this time that children learn what, how, when, and how much to eat based on the parental transmission of habits and attitudes related to eating (6). Children's vulnerability to this excessive exposure to unhealthy food choices, has contributed to an increase in overweight prevalence values (7).

Worldwide obesity is now known to have tripled since 1975 (8). About 41 million children under the age of 5 and 340 million between the ages of 5 and 19 have pre-obesity or obesity (8). In Portugal, about 25% of children under 10 years of age are classified as such (9, 10). Obesity is a major threat to global public health and one of the key challenges of the 21st century in terms of incidence, prevalence and economic costs (11, 12). The economic impact of obesity in 2014 was estimated at around 2.8% of global gross domestic product (11). In addition to excessive health-care spending, obesity also imposes costs on lost productivity, permanent disability and even early death in adults (13). The economic consequences of childhood obesity can be categorized as direct or indirect. The direct consequences involve medical costs such as medication and medical appointments, while the indirect consequences involve, for example, school absenteeism (14). Moreover, obesity

is also associated with a high risk of developing physiological, social and psychological negative consequences (15) and several factor can influence its development. In addition to hereditary characteristics, lifestyle, and especially dietary intake, has a great influence (16).

The literature shows that having pre-obesity or obesity during childhood increases the risk of developing numerous medical conditions such as type-2 diabetes, liver steatosis, high blood pressure, sleep apnea, cardiovascular disease, asthma, depression, glucose intolerance, insulin resistance, orthopaedic problems, menstrual abnormalities and cancer (17-19). Until recently, some of these diseases were only found in adults, but now are becoming prevalent in children that have obesity. Childhood obesity also negatively affects school performance and increases the likelihood that children will miss school more often (20, 21).

Childhood is also a pivotal period for the development of healthy eating habits and behaviours that can often persist into adulthood and be associated with body weight (22-26). Eating habits and behaviours include factors that influence the amount of food ingested by children (e.g., eating stimuli), and the diet quality (e.g. eating preferences) (27, 28). Dietary preferences also play a major role as they strongly influence food intake and, consequently, influence diet quality and appetite-related eating behaviours (29). A healthy diet includes a balanced composition of nutrients as well as balanced eating behaviour. The latter consists of eating in the presence of hunger and at regular times (30). Most studies on the association between diet quality and eating behaviour focus only on isolated foods, not considering the complexity of food intake as a whole (31).

Eating patterns

In recent decades, from a methodological point of view, nutritional research has been dominated by a reductionist approach, focusing mainly on food or nutrients isolated (32). Through this approach, it was possible to understand how nutrients can affect the metabolism of the human body. However, with the increasing prevalence of diet-related chronic diseases such as obesity, efforts to better understand this phenomenon emerge and dietary patterns have become increasingly accepted as an important tool for the characterization of general diet (33). Thus, a more holistic approach arises, which 'represents a top-down method, begins with a more general view and develops into a specific reductionist approach to explaining a necessary point of view' (34), whereas the whole is more than the sum of its parts (35).

Dietary patterns in observational studies can be defined by two general approaches:

- A hypothesis-driven approach, commonly referred to as a *a priori* or index, which is defined as the score of various food items or nutrients determined a priori (36-38). A score or index-based approach can be a useful tool for assessing the extent to which an individual's diet meets specific dietary recommendations, as well as assessing diet quality. Identifying foods to include in the index and how the score will be applied are some of the decisions that need to be made. This approach has as its main advantages the fact that it is easily reproducible, interpreted and compared, as well as being easily transmitted to the general population (39-41);
- An exploratory approach, generally called a *a posteriori* standard, as they are based on data already available. Principal component analysis and cluster analysis are the main methods applied (42);

Traditional nutritional epidemiology have assessed dietary intake through independent individual nutrients or food intake. However, an approach that considers the interactions of various nutrients and foods to assess overall diet quality is necessary (43). Several diet quality indices were previously developed to assess compliance with national dietary recommendations, each of which requires a combination of foods and nutritional items, such as: Healthy Eating Index (44), Diet Quality Index (45, 46) , Nutrition Quality Index (45) and Mediterranean Diet Score (47, 48). Alternatively, Food-Based-Diet Quality Score is a validated tool for assessing diet quality across eight or ten components such as vegetables and fruits, protein foods, grains, dairy, oils and fats, and sugar-sweetened beverages. Although, currently there are only a few specific to children (49-52).

Several factors can influence eating habits, such as social and cultural factors and food availability (53). Research on this topic is scarce, but some studies have shown that eating patterns are established early in life and seems to track throughout childhood and probably through adulthood (54). Other studies found no association between eating patterns and eating behaviours in school-age children (55).

Diet tracking

Diet tracking consists of the stability or maintenance of food intake, nutrient intake or eating habits during a period of time. This continuity can be understood as positive or negative, depending on the habit or consumption under study. The lack of stability of an eating pattern occurs when there is a change from a considered healthy (or unhealthy) to a lower (or higher) quality one (26, 56). Knowledge and understanding of lifelong dietary

tracking can help to identify what are the more or less consistent consumptions and habits over time, and thus to create formulations and interventions, as well as key intervention moments, to improve health outcomes, such as obesity (57). Tracking of eating habits has mainly been assessed in adults or between adolescence and adulthood, while few studies have evaluated tracking of diet during childhood (26, 54, 57). Table 1 presents a summary of the results obtained in studies about tracking in childhood. Several studies analyse food intake tracking, both with individual food or using the diet as a whole. Most of the studies used an exploratory approach. In a European prospective population-based birth cohort study that evaluated the tracking of food intake from 4 to 7 years, regular to moderate tracking for fruit and vegetable intake was observed (54). Another study conducted with Brazilian children has obtained some level of tracking for diet quality (24). In general, previous studies assessing the diet tracking showed results with moderate or poor tracking (54, 58, 59). In Portuguese children, three distinct dietary patterns were described at 4 years of age: high in energy-dense foods (EDF), low in foods typically consumed at main meals and intermediate in snacks (Snacking), and higher in vegetables and lower in EDF (Healthier) (60). These dietary patterns tracked between 4 and 7 years, and girls following the EDF dietary pattern at 4 years of age had a significantly higher adiposity 3 years later, comparing to girls following the healthier pattern (61). Other aspects of children's eating habits, such as the overall quality of diet, have been less studied, particularly assessing the tracking of this eating dimension in childhood.

Table 1. Summary of the results obtained in studies about tracking in childhood

<i>Reference</i>	<i>Country</i>	<i>Age (years)</i>	<i>Statistical Methods</i>	<i>Dietary pattern or isolated food groups</i>	<i>Main results</i>
<i>Emmet PM, 2015 (62)</i>	England	7 to 10	Multiple regression analysis	Principal components analysis, cluster analysis, and reduced rank regression	The dietary patterns of the child at 7 years was a strong determinant of children's dietary pattern at 10 and 13 years.
<i>Northstone K, 2008 (54)</i>	England	3 to 9	Spearman's correlation	Principal components analysis	Regular to moderate tracking for fruit and vegetable intake was observed.
<i>Lee A, 2017 (63)</i>	Korea	7 to 9	Multiple regression analysis	Principal components analysis	Diet behaviours can change, and these changes can affect changes in dietary patterns.
<i>Mikkilä V, 2005 (64)</i>	Finland	6 to 21	Spearman's correlation	Principal components analysis	A clear tracking was observed in the eating patterns score.
<i>Rauber F, 2014 (24)</i>	Brasil	3 to 8	Paired t-test and McNemar's test	Healthy eating index	Diet quality tracks during childhood.
<i>Lioret S, 2015 (65)</i>	France	2,3 and 5	Spearman correlation coefficients	Principal component analysis	A moderate tracking of the diet from 2 to 5 years of age was found.
<i>Northstone K, 2013 (58)</i>	England	7 to 13	Logistic regression	Cluster analysis	A moderate tracking between the different patterns was observed.
<i>Vilela S, 2014 (66)</i>	Portugal	2 to 4	Multiple regression analysis	Energy-dense food groups	From 2 to 4 years, a positive tracking was found for energy-dense foods
<i>Durão C, 2017 (60)</i>	Portugal	4 to 7	Multinomial regression models	Latent class analysis	Dietary patterns tracked between 4 and 7 years

Eating Behaviours

Eating behaviours develop early in life through the combination of genetic predisposition, dietary preferences and natural responses to food (67, 68). Problematic eating behaviours are increasing among children, ranging from picky eating to uninhibited or overeating, including eating without hunger, eating fast or being highly responsive to a food stimulus (69-71).

Over time, psychometric instruments have been developed to detect individual differences in eating behaviours among children. There are several scales and questionnaires that have been developed by different authors, but more recent observational studies are usually based on three: Dutch Eating Behaviour Questionnaire (DEBQ) (72), Baby's Eating Behaviour Questionnaire (BEBQ) (73), and Children's Eating Behaviour Questionnaire (CEBQ) (74). The DEBQ, validated for children aged 7 to 12 years (72), is designed to measure three eating styles: 'emotional eating' (eating in response to internal emotional stimuli such as anger, anxiety and fear), 'external eating' external stimuli such as smell or sight) and 'restraint' (consciously restricting food intake to control body weight) (75). The BEBQ was developed for mothers of children from 0 to 3 months, during breastfeeding / bottle feeding, or retrospectively after the start of complementary feeding. Its items were derived from the CEBQ, with sub-dimensions covering 4 aspects: 'Enjoyment of Food', 'Food Responsiveness', 'Slowness in Eating' and 'Satiety Responsiveness' (73). CEBQ is probably the most widely used instrument for assessing children's eating behaviours and is described in detail below.

Children Eating Behaviour Questionnaire

The CEBQ was developed and validated by Jane Wardle and colleagues (74) for pre-school children, but it has been used in children up to 12 years of age (76-78). This scale is generally accepted as one of the most comprehensive psychometric tools for assessing eating behaviours and has been tested with high reliability and validity in several countries (79, 80), including Portugal (78, 81). Its goal is to capture individual differences between aspects of eating behaviour that may contribute to underweight or overweight (76). Its dimensions were obtained by research in the previous literature on the eating behaviour of children and adults, followed by qualitative interviews with parents about their children's eating behaviours. The CEBQ is a parent-reported questionnaire with 35 items, rated on a 5-point Likert frequency scale (never, rarely, sometimes, often and always), with scores from 1 to 5. It is organized into eight behavioural sub-dimensions: Food Responsiveness (FR),

Enjoyment of Food (EF), Desire to Drink (DD) and Emotional Over Eating (EOE) as a 'Food-Approach' appetitive traits, Satiety Responsiveness (SR), Slowness in Eating (SE), Food Fussiness (FF) and Emotional Under Eating (EUE) as 'Food-Avoidance' appetitive traits. Table 2 described the eight sub-dimensions as well as the items included in each of them.

Eating behaviours related to appetite and dietary habits may arise as a result of a combination of several factors, from biological, environmental and social to genetic inheritance, as well as natural responses to food and preferences.

Table 2 - Description and items of each CEBQ sub-dimensions

Dimension	Sub-dimension	Definition	Original items
Food Approach Eating Behaviours	Food Responsiveness (FR)	Measures eating in response to environmental food cues, referring sight or smell of highly palatable food and desire to spend time eating food (76).	12 My child's always asking for food. 14 If allowed to, my child would eat too much. 19 Given the choice, my child would eat most of the time. 28 Even if my child is full up, s/he finds room to eat his/her favourite food. 34 If given the chance, my child would always have food in his/her mouth.
	Enjoyment of Food (EF)	Represents a general interest in food and captures the extent to which a child finds eating pleasurable and desires to eat (76).	1 My child loves food. 5 My child is interested in food. 20 My child looks forward to mealtimes. 22 My child enjoys eating.
	Desire to Drink (DD)	A general desire to have a drink, particularly sugar-sweetened drinks (76).	6 My child is always asking for a drink. 29 If given the chance, my child would drink continuously throughout the day. 31 If given the chance, my child would always be having a drink.
	Emotional Overeating (EOE)	Represents increased eating in response to negative emotions, such as anger and anxiety (77).	2 My child eats more when worried. 13 My child eats more when annoyed. 15 My child eats more when anxious. 27 My child eats more when s/he has nothing else to do.
Food Avoidance Eating Behaviours	Satiety Responsiveness (SR)	Represents the degree to which a child regulates food intake, based on their perceived fullness (76).	3 My child has a big appetite. 17 My child leaves food on his/her plate at the end of a meal. 21 My child gets full before his/her meal is finished. 26 My child gets full up easily. 30 My child cannot eat a meal if s/he has had a snack just before.
	Slowness in Eating (SE)	Measures the speed of eating during the course of a meal, with a higher score representing a reduction in eating rate as a consequence of lack interest in food (77).	4 My child finishes his/her meal very quickly. 8 My child eats slowly. 18 My child takes more than 30 minutes to finish a meal. 35 My child eats more and more slowly during the course of a meal.
	Food Fussiness (FF)	Reflects a lack of interest in food and rejection of new foods (food neophobia), leading to the consumption of an inadequate variety of foods (77).	7 My child refuses new foods at first. 10 My child enjoys tasting new foods. 16 My child enjoys a wide variety of foods. 24 My child is difficult to please with meals. 32 My child is interested in tasting food s/he hasn't tasted before. 33 My child decides that s/he doesn't like food, even without tasting it.
	Emotional Undereating (EUE)	Represents decreased eating in response to negative emotions, such as anger and anxiety (77).	9 My child eats less when s/he is angry. 11 My child eats less when s/he is tired. 23 My child eats more when s/he is happy. 25 My child eats less when s/he is upset.

Environmental and social factors of eating behaviours

Socioeconomic context and family environment

There are several environmental factors - such as family and school environments, and the society and culture in which the child is inserted - that influence the child's diet quality and eating behaviour (82-84). In particular, the family exerts an important influence on the development of eating behaviour. Early in life, parents play a central role in their children's lives, and at the dietary level, they are responsible for shaping the family environment (29). Children tend to imitate role models, and eating behaviours are no different, being acquired through observation of parents, siblings and other caregivers (6, 85).

The quality of the diet is influenced by practices such as having breakfast and more frequent family meals (86, 87). Earlier studies indicate that children who take fewer family meals consume more energy and less fruit and vegetables, having a poorer diet quality (88). As children grow older, it is becoming increasingly important to make the home food environment a place that minimizes the opportunity for expression of appetite traits that facilitates excessive weight gain (89) such as food responsiveness, desire to drink and a lower satiety responsiveness.

Currently, obesity is closely related to low socioeconomic conditions, which are also a strong determinant of infant food intake (90). Other social factors, such as increased maternal education, have also been associated with healthier food intake (91). Low levels of maternal education have been associated with lower adherence to healthy eating recommendations (23, 92, 93). Maternal age also seems to influence the eating quality and eating behaviour of children, since the children of younger mothers have a lower food quality (94, 95). A more recent study found that low education and lower maternal age are associated with overeating in children (81). Maternal diet has been referred as an important factor associated with children's diet (60). Maternal consumption is a strong predictor of their own children's fruits, vegetables, soft drinks and sweets consumption, affecting their diet quality (96). At these ages, it is also the mother who provides most of the child's food, and food eaten outside is influenced by food eaten at home (23).

Early life factors

Breastfeeding is the recommended feeding method exclusively during the first 6 months of life and at least up to 12 months of complementary nature (97). Given its immunological properties and its association with normal growth support, a growing body of literature has suggested that it might provide a small protective effect against obesity (98, 99). The benefits of breastfeeding for the health of children, both in the short and long term, vary from reduced child morbidity and mortality to the protective effect on chronic and metabolic diseases (100-102). In addition to exclusive breastfeeding, complementary breastfeeding, has presented a lower risk of developing overweight years later (103). Related with dietary intake, longer duration of breastfeeding has been linked to higher fruit and vegetable intake in childhood (104). Breastfeeding has also been associated with higher satiety responsiveness, while formula feeding has been associated with higher food fussiness (105-107).

Gestational diabetes and weight gain during pregnancy are important prenatal predictors of the development of obesity (108, 109). Intrauterine exposure to diabetes mellitus increases the risk of long-term adverse outcomes, which may also be explained by the mother's unhealthy eating habits during pregnancy (108).

In Portugal, in the Generation XXI, a population-based birth cohort, a study was conducted that showed that mothers who gained 16kg during pregnancy, compared to mothers who only gained 9kg, were more likely to have overweight or obese children during the first years of life (110), probably because the mothers who gained the most weight had poorer diet quality.

Maternal smoking during pregnancy may also interfere with the child's health. Recent studies show that smoking mothers during pregnancy have children who may have an appetite more susceptible to food stimuli (81). Food intake may also be influenced by this condition, as well as the likelihood that they developed overweight childhood, with poorer diet quality (111). The mechanisms by which maternal smoking during pregnancy influence children's diet and weight are not well studied. However, there are several hypotheses that have been raised. One is that nicotine in tobacco acts to reduce weight, and its abstinence increases food intake, which leads to weight gain (112-114).

Child's characteristics

More sedentary behaviour, such as longer hours of television viewing and no physical activity at all, might be associated with poorer diet quality and a more avid appetite (81). This association can be explained by the fact that children may be more likely to overeat when watching TV, including foods high in sugar and fat, and may even learn unhealthy eating habits through advertisements and programs (115). Watching longer television was also associated with an increased risk of developing obesity. Thus, parents should be aware of their decisive role, limiting the time of television exposure and increasing the time of non-sedentary activities (88).

Eating behaviours are a characteristic of the child as well, closely related to appetite, and both are influenced by social, biological and environmental factors (116). The stability of these behaviours throughout their lives demonstrates how children interact with their eating environment (89). Some appetite-related eating behaviours such as slowness in eating, enjoyment of food, food fussiness and satiety responsiveness appear to be hereditary (83). Others are influenced by the family environment, which includes eating behaviour and attitudes toward parents' food (29).

Previous studies have shown that certain sub-dimensions of eating behaviour, such as enjoyment of food and food responsiveness, have been associated with higher body weight and obesity in children, while higher scores for satiety responsiveness and slowness in eating have been associated with a lower risk of overweight (117-120). Some studies also relate eating behaviour with eating preferences. Higher enjoyment of food and food responsiveness scores were associated with higher consumption of protein-rich foods (such as meat), and vegetables and fruits, while satiety responsiveness and food fussiness were associated with lower consumption of these foods (121). Children with these traits may be at risk of inadequate energy intake and various nutrients. In addition, children with higher food fussiness have lower total fat, protein and dietary fiber intake (91, 122).

Biological factors

The influence of diet on certain appetite mechanisms has been supported by biological studies. Despite the great influence of environmental factors, biological factors also play a role in regulating appetite and food intake. Several models explain this biological process, highlighting the importance of homeostatic and hedonic pathways, which, despite having different functions, are not independent. The homeostatic pathway, by itself, allows

the regulation of the energetic balance and satiety, indicating the need for food intake as a consequence of the exhaustion of the energy stock. Homeostatic appetite control system is related to the satiety responsiveness (76). The hedonic pathway, in turn, prevails in periods when the stock of energy is abundant and increases the desire to consume highly pleasurable foods, like foods rich in fat and sugar (123). Hedonic appetite control system is related to the food responsiveness (76). The interaction between these two pathways is of great importance as it allows to maintain the balance between eating by necessity and eating for pleasure or as a reward (124).

Diet composition has also been shown to influence certain appetite mechanisms, namely those related to satiety (125). For example, the high protein value of the meal may influence the increased satiety and decreased hunger sensation (126). Proteins induce satiety, increase gastrointestinal hormone secretion, and increase diet-induced thermogenesis (127). The deregulation of caloric intake for a positive energy balance also depends on the energy density and palatability of the diet (128).

Genetic Predisposition

Food preferences are important predictors of food intake, and consequently of appetite-related eating behaviours and the quality of children's diets. These preferences are the result of a combination of genetic and environmental factors (129). From the beginning of life, it is well established that sweet flavours (e.g. fruit and yoghurt) are better accepted than bitter and sour flavours (e.g. vegetables) (28, 130). Babies do not need to learn preferences for the most basic tastes (sweet, salty, sour, bitter and umami). Instead, they are more predisposed to flavours that they perceive as more pleasing (131).

Few studies relate food preference and heritability across a large sample. Recently, one study was the exception and used a large sample of twins to realize the genetic influence on food choices. In this study we found a high heritability for protein foods (78%), and a moderate heritability for fruits (51%), vegetables (37%) and desserts (20%) (132). Similarly, a previous study showed that taste for vegetables (54%), fruit (53%), dairy products (27%) and protein foods (48%) have some genetic basis (133).

The result of a previous study with children aged 9-11 years demonstrated heritability for Satiety Responsiveness (63%) and Food Responsiveness (75%) (82). Neophobia is also strongly influenced by genetics, with studies proving its high heritability (78%). Studies on twins from Finnish and British families have shown heritability results for neophobia

estimated at 69% and 67%, respectively. Slowness in eating, satiety responsiveness, food responsiveness and enjoyment of food have been shown to be heritable (134).

The gaps of literature

This thesis will focus on the tracking of diet quality and appetite-related behaviours, which may be influenced by environmental, socioeconomic and genetic factors. Any specific eating habits during childhood may have a major impact immediately or later in adulthood. Given that food intake has previously shown some degree of stability over time, it is important to evaluate its direction and monitoring from early to late childhood. Tracking of eating habits is mainly assessed in adults or between adolescence and adulthood, while few studies have evaluated diet quality tracking during childhood (26, 54, 57).

Appetitive behaviours are established early in life and it seems to be influenced by important genetic factors. Nevertheless, environmental impact cannot be ruled out leaving us space to modify less healthy behaviours. Research on the influence of early eating habits on appetitive behaviours using a prospective approach is scarce and usually focuses only on breastfeeding or complementary feeding (70, 135).

Aims

This study aims to evaluate the tracking of diet quality in childhood, related factors and its association with appetitive behaviours. To answer this main objective, data was used from a Portuguese population-based birth cohort (Generation XXI) and the two following specific objectives were defined, resulting in two papers:

1. To evaluate the tracking of food consumption and diet quality from pre-school to school age, and its association with early life factors and maternal sociodemographic characteristics (paper I).
2. To assess the bidirectional associations between children's diet quality and appetitive behaviours during childhood (paper II).

Papers

Paper I

**Adherence to a healthy eating index from pre-school to school age
and its associations with sociodemographic and early life factors**

Adherence to a healthy eating index from pre-school to school age and its associations with sociodemographic and early life factors

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(Submitted 17 July 2018 – Final revision received 25 March 2019 – Accepted 15 April 2019; First published online 24 July 2019)

Abstract

Childhood is considered an important period for the development of healthy eating behaviours. This study aimed to evaluate the influence of early life factors and sociodemographic characteristics, including early diet quality, on diet quality at 7 years. The sample includes 5013 children evaluated at the ages of 4 and 7 years from the Portuguese birth cohort Generation XXI with complete information on FFQ. A healthy eating index was developed at both ages to assess adherence to the WHO's dietary recommendations, including eight food groups. Consumption quartiles were obtained for each group at 4 years and assigned a score between 1 and 4. A higher score represents a higher adherence to a better diet (range: 8 to 32). The associations between early life factors and sociodemographic characteristics and the score of the healthy eating index at 7 years were evaluated through linear regression models. The healthy eating index had an average score of 21.4 ± 3.53 (range: 12 to 32) at 4 years and 20.3 ± 3.36 (range: 11 to 31) at 7 years. After adjustment for confounders, a positive association was found between the healthy eating index at 4 and 7 years ($\beta = 0.384$, 95 % CI 0.356, 0.441). Maternal years of education ($\beta = 0.094$, 95 % CI 0.071, 0.116) and dietary score ($\beta = 0.182$, 95 % CI 0.155, 0.209) were positively associated with increasing dietary quality from 4 to 7 years. A healthier diet at preschool age, higher maternal education and a healthier diet increase the likelihood of maintaining a high healthy eating index score at school age.

Key words: Tracking; Cohort studies; Children; Dietary habits; Maternal behaviours

Childhood is a key period in life for the development of healthy eating habits that can persist for a long time^(1–5). The transition from pre-school to school can influence changes in children's food consumption⁽⁶⁾. Previous literature has shown that eating habits are established early in life and can be maintained throughout childhood; suggesting that the task of modifying behaviours at later stages will be challenging^(2,3). However, tracking of eating habits has mainly been assessed in adults or between adolescence and adulthood, while few studies have evaluated tracking of diet during childhood^(5,7–10). Understanding how children's eating patterns are acquired is essential in public health planning, particularly for supporting strategies to improve the quality of children's diet.

Maternal behaviours during and after pregnancy might modulate the child's nutrition status. In fact, children whose mothers smoked during pregnancy are more likely to be overweight throughout their lives^(11,12). Breastfeeding is also one of the factors that play a significant role in the establishment of long-term eating habits among children^(13–15) and its duration is inversely associated with the child's risk of being overweight later on⁽¹⁶⁾.

Childhood is also an important period for the development of healthy eating behaviours⁽⁶⁾. During this period, food choices can be influenced by several environmental factors⁽¹⁷⁾, such as parental behaviours (e.g. parental food habits) and family characteristics^(18–21). In particular, parental sociodemographic status seems to have a strong influence in children's food intake, since low levels of maternal education have been associated with lower compliance with dietary recommendations^(2,20,22), and with a higher consumption of energy-dense foods (EDF)⁽¹⁸⁾, compared with children of mothers with higher education levels. This negative effect of lower education levels on children's food intake might be, in part, the result of parents' poorer health literacy (e.g. ability to obtain, process and apply basic health information)^(23,24).

Nevertheless, children with older and well-educated mothers tend to have a healthier diet^(25,26). Maternal age also appears to be an important determinant, as children of younger mothers seem to have a diet similar to that of children of less-educated mothers, presenting, for instance, lower consumption of whole-wheat bread and fruit^(25,27).

Abbreviations: EDF, energy-dense foods; SSB, sugar-sweetened beverages.

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Understanding whether children's food consumption changes during childhood, when food consumption remains stable and what factors influence diet is important since it allows to formulate interventions that promote a healthy diet at an early childhood stage^(3,28,29). Thus, the present study aimed to evaluate the tracking of food consumption, including the evaluation of a score of a healthy eating index in pre-school and school age and its association with early life factors and maternal socio-demographic characteristics.

Methods

Participants

The present study was based on the population-based birth cohort Generation XXI⁽³⁰⁾. For this cohort, all newborns in the five public maternity hospitals in the metropolitan area of Porto were invited to participate, between 2005 and 2006. Of invited mothers, 91.4 % agreed to participate, with a total of 8647 children enrolled at baseline. At 4 years of age, the first follow-up of the entire cohort was performed, with 86 % of the children being evaluated. The second follow-up was performed at 7 years of age, and 80 % of the children were re-evaluated. During the follow-up periods, participants were invited to participate in a face-to-face interview. For those families that were not able to be present during the face-to-face interview, data were collected by telephone with a shorter version of the questionnaire. For the final sample, we considered all children with complete information on dietary habits consumption in the FFQ at both ages (*n* 5046). After exclusion of children with diseases that might influence the analysis of food intake (celiac disease, allergy and food intolerance, *n* 15) and children with congenital malformations that might affect feeding (*n* 18), 5013 children were included in the final sample.

Data collection

Data were collected by trained interviewers using structured questionnaires. The following variables collected at baseline were included in the present study: maternal sociodemographic characteristics at delivery (maternal working status, age and complete years of education), maternal and child characteristics during pregnancy and delivery (gestational diabetes, hypertension status, smoking status during pregnancy and weight gain during pregnancy; child's sex, birth weight and birth weight for gestational age), being that the latter represent more the weight of metabolic and/or genetic factors. From the 4-year follow-up evaluation, we have included maternal and child's BMI and both dietary intake, child's physical activity and if the child was breast-feeding and the respective duration. From the 7-year follow-up, the children's dietary intake and BMI were used.

Child's dietary intake

Data on children's food consumption were collected through an FFQ, applied by trained interviewers to the main caregiver of the child (usually the mother), referring to the 6 months prior to the interview, at both ages^(31,32). At 4 years, the FFQ asked the frequency of intake of thirty-five food items, while at 7 years, the FFQ included thirty-eight food items. The nine possible

frequency options were converted into daily consumption frequencies, ranging from 'never' to '≥4 times per d'. Similar food groups were created at both ages, based on the food recommendations of the Portuguese food wheel guide⁽³³⁾: 'Dairy products' (semi-skimmed milk, skimmed milk, cheese and yogurts); 'Meat and meat products' (pork, beef, rabbit, poultry and processed meat); 'Fish and eggs'; 'Cereal products and potatoes' (rice, pasta, potatoes, bread and semi-sweet type biscuits); 'Fruit and vegetables' (vegetable soup, raw and cooked vegetables, fruit and fresh fruit juice); 'Sweet foods' (cakes, sweet pastry, chocolate, chocolate powder, chocolate milk and candies); 'Salty snacks' (crisps, pizzas and burgers) and 'Soft drinks' (sweetened carbonated drinks and other sweetened drinks, including diet drinks).

In a subsample of children, dietary intake was also collected using 3-d food diaries, two weekdays and one weekend day, at 4 and 7 years of age (*n* 2993), completed by the main caregiver^(31,34). Parents were asked to record all the foods and drinks that children had consumed during those days, describing the amount, brand, recipe and place of consumption, through food diaries. The codification process was conducted *a posteriori* by a team of trained nutritionists, and nutrient intake was estimated using the software Food Processor SQL⁽³⁵⁾.

Healthy eating index

A healthy eating index, based on the WHO's dietary recommendations, previously developed⁽³⁶⁾ for children at the age of 4 years, was adapted in this study. This index was developed to evaluate the quality of diet at 4 and 7 years of age and includes the eight previously defined food groups. For each food group, at 4 years, quartiles of the frequency of consumption were obtained and a score was assigned ranging from 1 to 4 points. The same cut-off points obtained to define the quartiles at 4 years of age were also used at 7 years. For foods that are considered healthier, such as fruit, vegetables, dairy products, fish and eggs, the lowest consumption quartile was scored with 1 point, intermediate quartiles with 2–3 points and the highest consumption quartile was scored with 4 points. Food groups with less healthy foods, such as meat, meat products, salty snacks, sweet foods and soft drinks, the score was assigned inversely, that is, the highest consumption quartile was assigned the lowest score. Scores assigned were summed up, resulting in an index with a total score ranging from 8 to 32 points at both ages, with higher scores reflecting a better adherence to dietary recommendations.

To validate the healthy eating index, we used dietary information collected through 3-d food diaries. We compared the healthy eating index score with nutrient intake evaluated by food diaries. The information used in the validation was children's total energy intake (kJ/d), the percentage of energy from carbohydrates, proteins and fat and the fibre intake (g/d), at both ages. We predict that children with higher scores will have a higher intake of fibre and a lower intake of total fat and energy.

Other child's characteristics

A detailed description of newborns' anthropometrics is described elsewhere⁽³⁷⁾. Briefly, birth weight was abstracted from medical records by trained interviewers at the baseline evaluation. During the hospital stay, trained examiners weighed babies to



the nearest 1 g using infant scales. Birth weight adjusted for gestational age was computed as a continuous variable according to the Canadian reference⁽³⁸⁾. Accordingly, children were categorised as small for gestational age (children with birth weight below the 10th percentile for their gestational age and sex), appropriate for gestational age or large for gestational age (children weighing above the 90th percentile for their gestational age and sex).

Objective measurements of children's height and weight at 4 and 7 years were performed by a team of trained examiners, according to standard procedures. Children's BMI was defined by weight in kilograms divided by height in metres squared. This variable was then categorised using specific cut-offs for sex and age as defined by the WHO⁽³⁹⁾ (underweight/normal weight (≤ 1 sd); overweight (> 1 sd to ≤ 2 sd); obesity (> 2 sd)). A combined variable was created to evaluate the stability of BMI categories from 4 to 7 years of age: 'maintain: normal weight' (children with normal weight at both ages), 'maintain: overweight/obesity' (children with overweight or obesity at both ages), 'increase' (children that change from normal weight at 4 years to overweight or obesity at 7 years) and 'decrease' (children that change from overweight or obesity at 4 years to normal weight at 7 years).

Regular practice of structured physical exercise was used as qualitative variable and children were classified as non-practitioners or practitioners. The variable breastfeeding, collected as any breastfeeding duration in weeks, was categorised as never or less than 16 weeks, between 16 and 20 weeks and more than 20 weeks.

Maternal characteristics

Maternal working status at baseline was evaluated as a nominal variable, converted into working (part or full-time and working student) and not working (unemployed, student, seeking the first job, incapacitated and retired). As described earlier⁽⁴⁰⁾, mothers were considered as having gestational diabetes or hypertension during pregnancy when recorded on obstetrical records as a diagnosis during the current pregnancy. Maternal smoking status was asked at baseline for each of the pregnancy trimesters and categorised as not smoking or smoking during that period (less than one cigarette/d or at least one cigarette/d, respectively). Weight gained during pregnancy was obtained by subtracting the self-reported final pre-delivery weight by the preconceptional weight, and the results were categorised as ≤ 10 , > 10 and ≤ 20 , > 20 kg.

Objective measures of maternal height and weight were performed when the child was 4 years of age by a team of trained examiners, according to standard procedures. Maternal BMI was defined by weight in kilograms divided by height in metres squared. This variable was then categorised as normal or underweight (< 25 kg/m²) and overweight/obese (≥ 25 kg/m²), according to the WHO cut-offs⁽⁴¹⁾.

Information on maternal dietary intake at the 4 years evaluation was collected through an FFQ adapted from a previous questionnaire validated for the general adult population⁽⁴²⁾ and for pregnant women in a subsample of this cohort⁽⁴³⁾. This FFQ collected information on food intake during the previous year and included eighteen food items with nine response options

ranging from 'never' to 'four or more times per d'. Frequencies of consumption were converted into daily frequencies. A maternal food index previously developed was used in this study to evaluate the influence of maternal food intake on the child's food intake⁽⁴⁴⁾. Briefly, a score was obtained considering eight food items/groups: milk, fish, red meat, bread, fruit, vegetables, EDF and sugar-sweetened beverages (SSB). For each item/food group, quartiles of the frequency of consumption were obtained and a score was assigned with a range from 1 to 4 points, according to increasing quartiles of food consumption (milk, bread, fruit and vegetables) or decreasing quartiles of food consumption (red meat, EDF and SSB). The food score ranged from 8 to 32 points, where higher scores represent better dietary quality.

Ethical considerations

The Generation XXI project was conducted in accordance with the guidelines defined in the Declaration of Helsinki, and all procedures involving human subjects were approved by the Ethics Committee of the Hospital de São João/University of Porto Medical School. The legal representatives of each participant were informed about benefits and potential discomforts, through written informed consent, with the information of all the examinations to be carried out during the evaluation, at baseline and in the subsequent follow-up evaluations.

Statistical analyses

Categorical variables were described as frequencies and compared using the McNemar test. Continuous variables were summarised by means and standard deviations or medians and interquartile ranges. Comparison between groups was performed using Student's *t* test for paired samples or the Wilcoxon test, respectively. The change in score on the healthy eating index at both ages was compared using Student's *t* test for paired samples. The correlation between nutrient intake and the score of the healthy eating index, at both ages, was obtained using the Pearson correlation coefficient.

The associations between the score of the healthy eating index at 4 years, early life factors and sociodemographic characteristics, and the score of the healthy eating index at 7 years were evaluated through linear regression models – regression coefficients (β) and respective 95 % CI. In order to analyse the direct and indirect associations between exposures (family and maternal characteristics) and the outcome, a step-by-step approach was used: predefined blocks of variables were fitted separately, with each block mutually adjusted, and introduced cumulatively into the analysis, with a fixed order. Model 1 was adjusted for maternal sociodemographic characteristics (maternal age, education and work status at delivery); model 2 was further adjusted for maternal and child's characteristics during pregnancy and at delivery (gestational diabetes, hypertension, weight gain during pregnancy, smoking status, child's weight for the gestational age and breastfeeding); model 3 included those variables in model 2 plus maternal and child's characteristics at the 4 years evaluation (maternal BMI, maternal dietary score and child's physical exercise); model 4 included all the previous variables plus the healthy eating index score at 4 years; finally, model 5 included all the previous variables plus children BMI's stability from 4 to



7 years. An interaction effect between child's BMI stability and maternal BMI was tested in model 5 by including an interaction term in the final models. All models were adjusted for child's sex. Models' goodness-of-fit was evaluated through adjusted R^2 .

The software used was the Statistical Package for the Social Sciences (released 2011. IBM SPSS Statistics for Windows, version 22.0.; IBM Corp.). We considered a significance level lower than 0.05.

Results

Table 1 shows the sociodemographic and early life characteristics. At baseline, mothers presented a mean age of 30 (sd 5.2) years, had an average of 11 (sd 4.3) years of education and 77 % were working. Among the children included in the analysis (49 % girls), the majority were normal weight at both ages; only

0.5 % were underweight. However, the percentage of obese children increased from 4 to 7 years old (9.8 v. 15.0 %).

Table 2 presents the comparison of daily dietary intake and the scores in the healthy eating index, between 4 and 7 years of age. The daily frequency of consumption of 'Meat and meat products', 'Fish and eggs', 'Sweet foods' and 'Soft drinks' increased significantly from 4 to 7 years. However, the frequency of consumption of 'Cereal products and potatoes' and 'Dairy products' has decreased in the same period. The proportion of children who followed the Portuguese dietary recommendations for healthy foods and the proportion of children who consumed daily EDF are also described in Table 2. At the age of 4 years, almost 90 % of the children consumed 'Dairy products' at least three times per d, while at the age of 7 years, there was a significant decrease in the daily frequency. From 4 to 7 years, there was an increase in the proportion of children with daily consumption of 'Meat and meat products' (72 v. 80 %, 0.5 % were underweight. However, the percentage of obese children increased from 4 to 7 years old (9.8 v. 15.0 %).

Table 1. Sociodemographic characteristics, pregnancy and early-life characteristics (Mean values and standard deviations; numbers of participants and percentages)

	Evaluation					
	Baseline		4 years		7 years	
	n	%	n	%	n	%
Maternal age (years)						
Mean		29.8		—		—
SD		5.2				
Maternal level of education (years)						
Mean		11.1		—		—
SD		4.3				
Maternal working status (working)	3940	77.1	—		—	
Gestational diabetes	274	5.7	—		—	
Hypertension during pregnancy	43	0.8	—		—	
Weight gain during pregnancy (kg)			—		—	
Mean		13.6				
SD		5.8				
Smoking during pregnancy						
First trimester	1028	20.0	—		—	
Second trimester	672	13.2	—		—	
Third trimester	626	12.3	—		—	
Maternal BMI (kg/m ²)		—				
Mean		—	26.4		—	
SD		—	5.1		—	
Maternal dietary score		—				
Mean		—	18.8		—	
SD		—	3.7		—	
Girl	2462	49.1				
Weight gain during pregnancy						
≤10 kg	1323	28.2				
>10 and ≤20 kg	2914	62.0				
>20 kg	461	9.8				
Child's birth weight for gestational age						
Appropriate for gestational age	4226	82.3	—		—	
Small for gestational age	728	14.1	—		—	
Large for gestational age	186	3.6	—		—	
Breastfeeding						
<16 weeks			2058	39.8	—	
≥16 and ≤20 weeks			601	11.7	—	
>20 weeks			2487	48.3	—	
Child's practice of structured physical exercise	—		4393	85.3	—	
Child's BMI						
Underweight/normal weight	—		3433	69.2	3176	63.4
Overweight	—		1041	21.1	1076	21.5
Obesity	—		487	9.8	751	15.0

Table 2. Children's dietary intake at 4 and 7 years of age (Mean values and standard deviations; numbers of participants and percentages; medians and interquartile ranges (IQR))

	Age 4 years		Age 7 years		P
	n	%	n	%	
Dairy products (frequency/d)					<0.001*
Mean		4.43		4.18	
SD		1.45		1.70	
Dairy products ($\geq 3/d$)	4004	87.4	3825	74.9	<0.001*
Meat and meat products (frequency/d)					<0.001*
Mean		1.43		1.55	
SD		0.56		0.71	
Meat and meat products ($\geq 1/d$)	3287	71.8	4088	80.1	<0.001*
Fish and eggs (frequency/d)					<0.001*
Mean		0.77		0.87	
SD		0.30		0.35	
Fish and eggs ($\geq 5-6/\text{week}$)	2404	52.5	3260	64.0	<0.001*
Cereal products and potatoes (frequency/d)					<0.001*
Mean		4.61		4.42	
SD		1.33		1.25	
Cereal products and potatoes ($\geq 5/d$)	1784	35.6	1361	27.5	<0.001*
Fruit and vegetables (frequency/d)					<0.001*
Mean		4.64		4.50	
SD		1.54		1.65	
Fruit and vegetables ($\geq 5/d$)	1921	41.9	2022	39.1	0.008*
Sweet foods					<0.001†
Median		1.20		1.27	
IQR		1.44		1.37	
Sweet foods ($\geq 1/d$)	2705	52.3	3393	65.6	<0.001†
Salty snacks					<0.001†
Median		0.13		0.13	
IQR		0.14		0.13	
Salty snacks ($\geq 1/\text{week}$)	2238	44.6	2234	45.2	0.609†
Soft drinks					<0.001†
Median		0.57		0.92	
IQR		1.00		1.15	
Soft drinks ($\geq 1/d$)	1089	23.8	1771	34.3	<0.001†
Healthy eating index score					<0.001*
Mean		21.4		20.3	
SD		3.53		3.36	

*Student's *t* test for paired samples.

†Wilcoxon test.

$P < 0.001$) and weekly consumption of 'Fish and eggs' ($\geq 5-6/\text{week}$: 53 *v.* 64%, $P < 0.001$). At both ages, less than half of children were consuming five daily servings of 'Fruit and vegetables'. The proportion of children consuming 'Cereal products and potatoes' daily decreased from 4 to 7 years ($\geq 5/d$: 35.6 *v.* 27.5%). Around 45% of children consumed 'Salty snacks' weekly, at both ages. The daily consumption frequency of 'Sweets foods' and 'Soft drinks' increased significantly from 4 to 7 years (52 *v.* 66%, $P < 0.001$ and 23 *v.* 34%, $P < 0.001$, respectively). The healthy eating index score decreased slightly from 4 to 7 years (21.4 (SD 3.53) *v.* 20.3 (SD 3.63), respectively, $P < 0.001$). The scores ranged from 12 to 32 points at 4 years and from 11 to 31 points at 7 years (Table 2).

The correlation between the healthy eating index score at 4 and 7 years with nutrient intake was obtained through 3-d food diaries (Supplementary Table S1). At both ages, the healthy eating index was positively and significantly correlated with protein (r 0.111, $P < 0.001$ and r 0.157, $P < 0.001$) and fibre intake (r 0.205, $P < 0.001$ and r 0.253, $P < 0.001$), but inversely correlated with energy intake (r -0.060, $P = 0.006$ and r -0.063, $P < 0.001$), total fat intake (r -0.106, $P < 0.001$ at 4 years only) and saturated fat (r -0.141, $P < 0.001$ and r -0.073, $P < 0.001$). The intake of carbohydrates, monounsaturated and polyunsaturated fat did not present a statistically significant correlation

($P > 0.01$) with the healthy eating index scores, at both ages (Supplementary Table S1).

The relationship between a children's healthy eating index at 4 and 7 years, by tertiles, is presented in Fig. 1. Around 40% of the children who were in the lowest tertile of the score at 4 years of age continued in the lowest tertile at the age of 7 years, while the remaining moved to a higher tertile. Of those children within the second tertile of the healthy eating index score at 4 years of age, one-third remained in the same tertile at 7 years, 20% moved to the first tertile, while the remaining moved to a higher tertile. Of those children within the highest tertile of the score at 4 years, most remained in the highest tertile at 7 years (71%), while one-fifth moved to the second tertile and less than 10% moved to the first tertile.

In the analysis presented in Table 3, the associations were considered by consecutive addition of blocks into the model. An increase of 1 year in maternal age and maternal education was associated with a 0.06- and 0.22-unit increase in the healthy eating index at 7 years, respectively (model 1). When maternal behaviours at the 4 years evaluation were added (model 3), maternal age ceased to be significantly associated with the healthy eating index score at 7 years. An increase of one unit in the maternal dietary score was associated with an increase of 0.32 units in

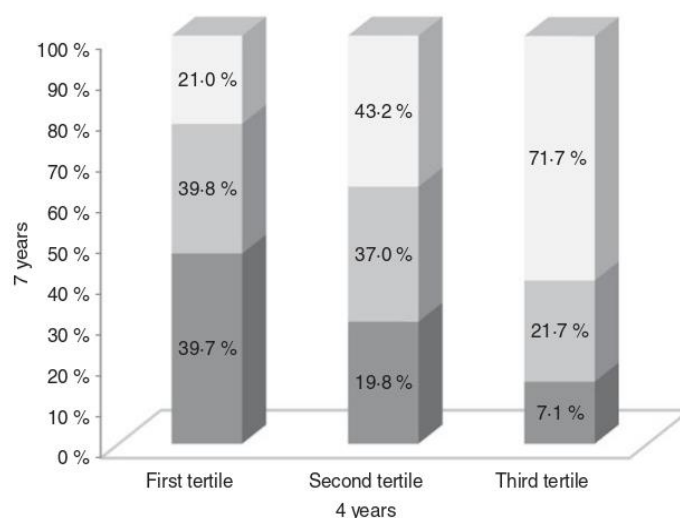


Fig. 1. Relationship between children's healthy eating index (tertile) at 4 years and their healthy eating index (tertile) at 7 years. ■, First tertile; ▨, second tertile; □, third tertile.

the healthy eating index score at 7 years (model 3). A one-unit increase in healthy eating index at age 4 years was associated with a 0.38-unit increase in the healthy eating index at 7 years (model 3). Also, in this model, maternal education and maternal dietary score remained significantly associated with an increased score of the healthy eating index from 4 to 7 years of age. The addition of the child's BMI stability in model 5 did not change significantly the previous associations. No association was found between early life characteristics (intra-uterine and infancy environment) and diet quality at 7 years of age.

Comparison between models was performed through the adjusted R^2 , which allows us to know the proportion of variation in the healthy eating index at 7 years that is explained by each model. Model 5 best explains this variation.

Discussion

The present study supports the hypothesis that food intake changes with the transition from pre-school to school years. These dietary modifications consisted mainly of an increase in the consumption of animal protein food sources (meat, fish and eggs), soft drinks and sweets, as well as a decrease in dairy products and cereals and potatoes consumption, which contributed to a lower score on the healthy eating index at 7 years.

The increased consumption of animal protein from 4 to 7 years is in accordance with previous studies that have shown that European adolescents greatly exceed the recommendations, mainly due to meat consumption⁽⁴⁵⁾. The decrease in daily consumption of dairy products may be related to the substitution of these foods by SSB, since in the same period, and as reported in other studies, there has been an increase in SSB consumption^(46,47). Indeed, a previous systematic review and meta-analysis showed that increased SSB intake is associated with a lower consumption

of milk and Ca, in both adults and children, although average effect sizes were small⁽⁴⁷⁾. Even though the consumption of fruit and vegetables remained constant between 4 and 7 years of age, less than half of the children have an intake of at least five times per d of this food group. Consumption of foods high in sugar and energy (SSB and sweet foods) increased significantly between the two ages. Attention should be given to this trend in childhood, as previously reported from 2 to 4 years of age⁽³⁵⁾, since these food groups are associated with adverse health outcomes, namely a higher risk of obesity in children⁽⁴⁸⁾.

Although the score on the healthy eating index decreased from preschool to school age, it was verified that the better the healthy eating index score at age 4 years, the better the healthy eating index score at age 7 years. This association might be sustained by the fact that the dietary pattern formed in the first years of life continues to strongly influence food intake, even if the child spends more time away from home. Another possibility is that although children are eating out-of-home more often, most of the food they consume is still consumed or prepared at home⁽⁴⁹⁾. The comparison between the healthy eating index score and child's nutrients intake obtained through food diaries showed that the index was indeed evaluating a better diet, at both ages. Moreover, the comparison of tertiles of the healthy eating index score at 4 and 7 years of age showed that children in the highest tertile at age 4 years were most likely to remain in the highest tertile at age 7 years. This was true to a lesser extent for the children in the lowest tertile.

Maternal education and diet were independently associated with a better diet quality at 7 years. These results are in concordance with previous studies that showed that healthier eating habits among pre-school and school children have been associated with higher maternal education^(2,22,27,50–52). Lower maternal education increases the probability of a poorer food quality diet in children, as this sociodemographic condition probably limits the

Table 3. Associations between maternal and child characteristics and adherence to a healthy eating index at 7 years of age (β -Coefficients and 95 % confidence intervals)

	Model 1		Model 2		Model 3		Model 4		Model 5	
	β	95 % CI	β	95 % CI	β	95 % CI	β	95 % CI	β	95 % CI
Sociodemographic factors at child's delivery										
Maternal age (years)	0.062*	0.045, 0.080	0.053*	0.034, 0.072	0.002	-0.017, 0.020	-0.003	-0.021, 0.014	-0.003	-0.020, 0.015
Maternal education (years)	0.215*	0.193, 0.237	0.213*	0.190, 0.236	0.151*	0.128, 0.175	0.077*	0.055, 0.100	0.094*	0.071, 0.116
Maternal work status										
Working	Ref.		Ref.		Ref.		Ref.		Ref.	
Not working	-0.043	-0.268, 0.183	-0.005	-0.246, 0.235	0.037	-0.192, 0.265	0.094	-0.117, 0.305	0.095	-0.121, 0.312
Early life factors – at pregnancy and delivery										
Gestational diabetes										
No			Ref.		Ref.		Ref.		Ref.	
Yes			0.202	-0.216, 0.621	0.182	-0.214, 0.578	0.098	-0.267, 0.464	0.039	-0.337, 0.415
Maternal hypertension during pregnancy										
No			Ref.		Ref.		Ref.		Ref.	
Yes			0.640	-0.378, 1.658	0.831	-0.126, 1.788	0.754	-0.129, 1.637	0.771	-0.124, 1.667
Weight gain during pregnancy (kg)										
≤10			Ref.		Ref.		Ref.		Ref.	
>10 and ≤20			-0.125	-0.343, 0.093	-0.099	-0.306, 0.109	-0.119	-0.311, 0.072	-0.132	-0.328, 0.064
>20			0.001	-0.357, 0.359	0.110	-0.266, 0.453	0.032	-0.285, 0.349	0.073	-0.251, 0.397
Child's birth weight for gestational age										
Appropriate for gestational age			Ref.		Ref.		Ref.		Ref.	
Small for gestational age			-0.049	-0.324, 0.277	0.018	-0.245, 0.280	-0.025	-0.267, 0.218	0.005	-0.244, 0.253
Large for gestational age			0.232	-0.288, 0.753	0.208	-0.287, 0.703	0.136	-0.321, 0.593	0.068	-0.449, 0.585
Maternal smoking status during pregnancy										
First trimester										
No			Ref.		Ref.		Ref.		Ref.	
Yes			0.013	-0.349, 0.376	0.251	-0.095, 0.598	0.202	-0.118, 0.522	0.174	-0.152, 0.500
Second trimester										
No			Ref.		Ref.		Ref.		Ref.	
Yes			-0.754	-1.637, 0.128	-0.766	-1.604, 0.071	-0.728	-1.501, 0.046	-0.615	-1.40, 0.169
Third trimester										
No			Ref.		Ref.		Ref.		Ref.	
Yes			0.432	-0.427, 1.291	0.491	-0.323, 1.306	0.511	-0.240, 1.263	0.406	-0.356, 1.168
Breastfeeding										
<16 weeks			Ref.		Ref.		Ref.		Ref.	
≥16 and ≤20 weeks			0.183	-0.122, 0.487	0.071	-0.217, 0.359	0.070	-0.196, 0.336	0.010	-0.263, 0.283
>20 weeks			0.308*	0.102, 0.514	0.064	-0.133, 0.261	0.068	-0.114, 0.249	0.065	-0.122, 0.251
Maternal and child's behaviours at 4 years of age										
Maternal dietary score					0.323*	0.296, 0.349	0.172*	0.145, 0.198	0.182*	0.155, 0.209
Maternal BMI										
Normal or underweight (<25 kg/m ²)					Ref.		Ref.		Ref.	
Overweight/obese (≥25 kg/m ²)					-0.123	-0.310, 0.064	-0.072	-0.245, 0.101	-0.147	-0.381, 0.086
Child's structured physical exercise										
Non-practitioners					Ref.		Ref.		Ref.	
Practitioners					-0.212	-0.212, 0.314	0.041	-0.202, 0.284	0.062	-0.187, 0.311

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(Continued)



Table 3. (Continued)

	Model 1		Model 2		Model 3		Model 4		Model 5	
	β	95 % CI	β	95 % CI	β	95 % CI	β	95 % CI	β	95 % CI
Child's behaviours										
Dietary score at 4 years of age										
Child's BMI stability from 4 to 7 years of age										
Maintain: normal weight (57 %)										
Maintain: overweight/obesity (25 %)										
Increase (12 %)										
Decrease (6 %)										
Adjusted R^2	0.093		0.094		0.200		0.318		0.401*	0.372, 0.429
Ref. reference									Ref.	
									-0.121	-0.450, 0.208
									0.207	-0.197, 0.611
									-0.040	-0.552, 0.472
									0.333	

* Statistically significant associations.

† Blocks of variables (maternal sociodemographic characteristics during pregnancy and at delivery; maternal characteristics at 4-year evaluation; and children characteristics) were added sequentially into the analysis; models are adjusted for children's sex. Model 5 also includes an interaction effect between child's BMI stability and maternal BMI.

purchasing power and the ability to obtain adequate nutritional information⁽²⁾. Plus, this association might be partly explained by the importance of parents as role models for children's dietary intake. There is considerable evidence that children's eating behaviours, including food preferences, are very similar to that of their parents^(53,54). In concordance with previous reports, this study shows that maternal diet is one of the most important factors associated with the healthy eating index score at 7, with a better maternal dietary intake influencing the children's diet positively^(44,55). This suggests that particular efforts should be made towards nutritional education among less-educated mothers, encouraging them to adopt healthy eating habits^(25,26,54). Maternal work status may also influence dietary patterns in children, as was shown in a study in the UK⁽²⁾. The same was not observed in our study, as future analysis will be required to fully understand the matter.

Excessive gestational weight gain during pregnancy and gestational diabetes were previously recognised as prenatal determinants of childhood obesity^(56,57), which might be explained, in part, by the adoption of less healthy eating habits. However, we did not find any statistically significant association between these factors and the diet quality at 7 years. Moreover, maternal smoking status has been associated with children's dietary intake⁽²⁹⁾. Our results, however, are not in line with previous studies, which show an association between low scores in a healthy pattern and smoking during pregnancy⁽²⁹⁾. A recent study combining information from four European cohorts (the Habaat Project) concluded that never or short duration of breastfeeding (but not the timing of complementary feeding) were associated with a less-healthy diet in early childhood, including a lower consumption of fruit and vegetables⁽¹³⁾. However, in the present analysis, we did not find a significant association between breastfeeding and higher scores in the healthy eating index. This might be due to the reported longer breastfeeding duration time in Portugal, in comparison with other countries⁽¹³⁾.

These results should be viewed in light of some limitations. The FFQ was answered by parents, in a face-to-face interview, who might not be aware of every food offered to children when they are with other caregivers or in school. However, in a subsample of children from the Generation XXI cohort, dietary information collected from 3-d food diaries was compared with dietary data from the FFQ, supporting the validity of the results, particularly for those foods that are more frequently consumed⁽³¹⁾. Information about the duration of breastfeeding was collected only at the 4-year follow-up, which may represent a potential memory bias. In addition, for groups with minimum and maximum consumption, the proposed index is limited to assessing compliance with the WHO quantitative recommendations. Some parents might have also reported what, for them, the child is supposed to consume instead of what was actually consumed or report more healthy food and less unhealthy food. If this has occurred, our associations could be underestimated. The low correlation between the healthy eating index score and the nutrients' intake might be a threat to the external validation of the index. Nevertheless, this might be partly explained by the nature of the collection method and the usually obtained low to medium correlations obtained between FFQ and food diaries⁽³¹⁾.

The use of two methods to collect dietary intake information, food diaries and FFQ, can be considered a strength of this study, as it allows the reduction of report errors. The main strengths of the study are its longitudinal design, based on a relatively large sample size from participants of a population-based birth cohort regularly evaluated, with a high participation rate. This allows us to ensure a temporal sequence between several exposures and the tracking of children's dietary intake. Only children with complete FFQ data were considered in our sample. The comparison of baseline characteristics between participants and non-participants showed that mothers included in our sample were slightly older and more educated. However, these differences do not seem to be very relevant (Cohen's effect size values are not high: <0.40), and probably these differences are more likely to be due to large sample size rather than to substantial differences between participants. Finally, by performing the statistical analysis by models, we were able to easily identify the possible confounders of these associations.

Conclusion

This study suggests that promoting healthy eating habits at early ages is essential in order to prevent unfavourable eating habits later on. The quality of dietary intake decreases from preschool to school age and healthy eating habits established at 4 years influence healthy eating habits at 7 years. We could also verify that maternal sociodemographic and behavioural factors have a higher influence on the maintenance of healthy eating habits from 4 to 7 years, compared with metabolic or genetic factors. A higher maternal education and a healthier maternal diet increased the likelihood of children maintaining a healthy eating index score at school age. Interventions to promote healthy eating habits among preschool children should involve mothers as well. Greater focus should be given to those with lower education, with a particular emphasis on their diet and its consequences on children's healthy eating habits.

Supplementary material

To view supplementary material for this article, please visit <https://doi.org/10.1017/S0007114519001028>

Acknowledgements

The authors gratefully acknowledge the families enrolled in Generation XXI for their kindness, all members of the research team for their enthusiasm and perseverance and the participating hospitals and their staff for their help and support. The authors acknowledge the support from the Epidemiology Research Unit (EPI-Unit: UID-DTP/04750/2013).

Generation XXI was funded by the Health Operational Programme – Saúde XXI, Community Support Framework III and the Regional Department of Ministry of Health. It was supported by the Calouste Gulbenkian Foundation, by FEDER from the Operational Programme Factors of Competitiveness – COMPETE and through national funding from the Foundation for Science and Technology – FCT (Portuguese Ministry of Education and Science) under the project PTDC/SAU-EPI/

121532/2010 (FEDER-Operational Programme Factors of Competitiveness – COMPETE – FCOMP-01-0124-FEDER-021177), and the PhD grant SFRH/BD/92389/2013 (S. V.). FCT had no role in the design, analysis or writing of this article.

The authors' contributions are as follows: M. P. C. was responsible for the analysis and interpretation of the data and wrote the first draft of the paper; C. D., C. L. and S. V. were also responsible for the analysis and interpretation of the data. All authors contributed to the concept and design of the study and paper review.

There were no conflicts of interest.

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Supplementary Material

Supplementary Table 1. Correlation between the healthy eating index score at 4 and 7 years and the nutrients obtained by food diaries (n=2993).

Nutrient	4 years		7 years	
	Pearson Correlation	p-value	Pearson Correlation	p-value
Energy intake (Kcal)	-0.060	0.006	-0.069	<0.001
Protein (%TEI)	0.111	<0.001	0.167	<0.001
Carbohydrates (%TEI)	0.040	0.064	-0.022	0.238
Fat (%TEI)	-0.106	<0.001	-0.057	0.002
Saturated fat (%TEI)	-0.141	<0.001	-0.096	<0.001
Monounsaturated fat (%TEI)	-0.039	0.071	0.010	0.603
Polyunsaturated fat (%TEI)	0.003	0.894	-0.025	0.177
Fiber (g)	0.205	<0.001	0.246	<0.001
TEI, total energy intake				

Paper II

Bidirectional relationship between children's appetitive behaviours and diet quality from 7 to 10 years: a prospective cohort study

Abstract

Objective: This study aims to explore the relationship between appetite-related eating behaviours and diet quality, from 7 to 10 years of age.

Methods: The sample includes 3879 children evaluated at 7 and 10 years of age, from the Portuguese birth cohort Generation XXI, with complete information on a validated Food Frequency Questionnaire (FFQ) and the Children's Eating Behaviour Questionnaire (CEBQ), at both ages. A healthy eating index (HEI) (range: 9 to 31) was developed using data from the FFQ. The eight CEBQ sub-dimensions were considered. Generalized linear models were used to estimate the associations. An adjusted cross-lagged analysis was performed to study the direction of the associations.

Results: A bidirectional inverse association between the food fussiness sub-dimension and diet quality was found ($\beta_{\text{standardized}} = -0.033$ and $\beta_{\text{standardized}} = -0.030$, $p < 0.001$). A higher score in the HEI at 7 years-old was associated with lower scores of satiety responsiveness sub-dimension at 10 years-old ($\beta_{\text{standardized}} = -0.039$), while a higher score in the enjoyment of food sub-dimension at 7 years-old was associated with higher scores in the HEI at 10 years-old ($\beta_{\text{standardized}} = 0.046$).

Conclusion: Children with more enjoyment of food and a less food fussiness at 7 years of age are more likely to have a high-quality diet at 10 years of age. Children with high-quality diets at 7 years of age are more likely to have less food fussiness and satiety responsiveness at 10 years of age. Different strategies should be considered to intervene early in the acquisition of eating behaviours and eating habits.

Keywords: diet quality, CEBQ, healthy eating index, cohort study

Introduction

Childhood obesity is one of the most serious public health problems of the 21st century (1). Currently, more than 340 million children have pre-obesity or obesity worldwide (2). In Portugal, about a quarter of children are also classified as such (3). Children with obesity have a greater risk of developing severe pathologies in the future (e.g., type II diabetes, coronary heart disease and stroke) in both the short and long term (4-7). Compared to normal weight children, children with overweight are more likely to maintain an unhealthy body weight as adults, as well as having an increased risk of premature death (8). In addition to some inherited characteristics, lifestyle, especially diet, is one of the main drives of the high prevalence of obesity (9).

Childhood has been described as a pivotal period for the development and establishment of healthy eating habits (10-12). It has been suggested that poor eating habits and behaviours established early in life remain stable in subsequent years (13-15). Therefore, it is essential to discourage them since the beginning of life.

A balanced eating behaviour consists of eating when feeling hungry, at regular times, and especially foods with a balanced nutrients composition (16). However, in Western society, a contrary behaviour is increasingly observed, with a growth in the tendency to eat in the absence of hunger, rapid eating and eating in response to environmental food cues (16). These behaviours may lead to increased high energy-dense foods consumption, and in turn, to weight gain.

Poor diet quality in early childhood, with high energy-dense and fat, and low in fiber, has been associated with a predisposition to later overweight and obesity (17, 18). Also, some appetite traits have been associated with body weight. A high enjoyment of food and a high responsiveness to external food cues ('Food Responsiveness') have been linked with an unhealthy percentage of body fat and obesity in children (19, 20).

Previous studies on the influence of eating habits on appetite-related eating behaviours generally focus only on breastfeeding or complementary feeding (21, 22). Only a previous study has described a bidirectional association regarding children's eating habits, namely as eating frequency, and children's eating behaviours related to appetite (23). Moreover, appetite traits and diet quality were previously identified separately as predictors of infant feeding (24, 25). This study aims to improve the understanding of the establishments of appetite-related eating behaviours in childhood and its relationship with diet quality during childhood. It aims to explore the bidirectional relationship between appetite-related eating behaviours and diet quality, from 7 to 10 years of age, using a cross-lagged analysis.

Methods

Study design and Participants

The present study was based on the previously described population-based cohort Generation XXI (26). For this cohort, 8647 children and their mothers were recruited, between 2005 and 2006, in the 5 public maternity hospitals in the metropolitan area of Porto. Of the invited mothers, 91.4% accepted to participate. At 4 years of age, the first follow-up of the entire cohort was performed, with 86% of the children being evaluated. The second follow-up was performed at 7 years of age, with a re-evaluation of 80% of the children. At 10 years, a new follow-up was carried out, with a total of 76% of the children evaluated. During these evaluation waves, participants were invited to participate in a face-to-face interview. Data were collected by trained interviewers using structured questionnaires about demographic and social conditions, lifestyles, child's health status, and objective anthropometric measures were performed. For families that were not available to participate in person, the evaluation was conducted over the phone with a shorter version of the questionnaire. For the final sample, we considered all children who performed follow-up with a face-to-face interview, providing data at 7 and 10y, with complete information on dietary consumption collected by the food frequency questionnaire (FFQ) and information from the Children's Eating Behaviour Questionnaire (CEBQ), at both ages. After exclusion of twins (n=144) and children with congenital anomalies or diseases that might influence the analysis of food intake (celiac disease, allergy and food intolerance) (n=50), we achieve a final sample of 3879 children.

The Healthy Eating Index (HEI)

Data on children's dietary consumption was collected through a FFQ, applied by trained interviewers to the child's primary caregiver (usually the mother), assessing usual consumption in the previous 6 months, at both ages. At 7 years, FFQ, previously calibrated in this sample (27), asked the frequency of consumption of 38 food items, while at 10 years the FFQ have included 41 food items. Nine response options, varying between 'never' to '≥4 times per day', were converted into daily consumption frequencies.

An healthy eating index (HEI), previously developed to evaluate children's diet quality (28, 29), was adapted for this study to evaluate children's diet at 7 and 10 years of age. Briefly, similar food groups were created at both ages, based on dietary recommendations of the Portuguese food wheel guide (30): 'Dairy', 'Meat and meat products', 'Fish and eggs', 'Cereal products and potatoes', 'Fruit and vegetables', 'Sweet foods', 'Salty snacks' and 'Soft drinks'. At 7 years, quartiles of frequency of consumption were obtained for each food group, and at

10 years, the same cut-off points were used. The score was assigned from 1 to 4 points. For foods considered healthier (such as dairy, vegetables, fruits, fish and eggs), the lower consumption quartile was scored with 1 point, intermediate quartiles with 2 and 3 points, and the highest consumption quartile was scored with 4 points. For foods considered to be less healthy (such as meat and meat products, sweet foods, salty snacks and soft drinks), the score was reversed. Scores assigned were summed up, resulting in a total score ranging from 8 to 32 points at both ages, with higher scores reflecting a better quality of the diet.

Eating Behaviours

In the present study, eating behaviours were obtained at 7 and 10 years, through the self-completion of the Portuguese version of the CEBQ, mostly by the mothers (31). This instrument is a parent-report questionnaire that measures appetite traits in children, and was previously tested in this population demonstrating good psychometric characteristics (31). The original CEBQ includes 35 items, answered on a five-point Likert scale ranging from never to always, scored from 1 to 5. The present study includes the eight sub-dimensions: 'Food Responsiveness' (FR), 'Enjoyment of Food' (EF), 'Satiety Responsiveness' (SR), 'Slowness in Eating' (SE), 'Desire for Drinks' (DD), 'Food Fussiness' (FF), 'Emotional Over Eating' (EOE) and 'Emotional Under Eating' (EUE). In accordance with the original scale, five of the items were reverse-scored due to opposite phrasing. In children with missing data less than 50% (around 3%), missing data were attributed by imputation, replacing the average of the remaining questions within the same sub-dimensions.

For the current sample, Cronbach alpha coefficients for each CEBQ sub-dimensions were calculated to assess the internal consistency of each sub-dimensions and ranged from 0.67 (EOE) to 0.79 (FR) at 7 years, and from 0.65 (EOE) to 0.84 (FF) at 10 years of age.

Other child's and maternal characteristics

From the baseline evaluation, we have used in the present study the maternal age and complete years of education. From the follow-up at 7 and 10 years, we have included child's sex, child's z-score body mass index (BMI) and child's regular practice of physical activity (as a categorical variable 'no' vs. 'yes').

Objective measurements of children's height and weight at 7 and 10 years were performed by a team of trained examiners, according to standard procedures. Children's BMI was defined by weight in kg divided by height in m². This variable was categorized using specific cut-offs for sex and age, as defined by the WHO [Underweight/Normal weight (≤ 1 Standard Deviation (SD)); Overweight (> 1 sd to ≤ 2 sd); Obesity (> 2 sd)] (32).

Ethical considerations

The Generation XXI project was conducted in accordance with the guidelines defined in the Declaration of Helsinki, and all procedures involving human subjects were approved by the Ethics Committee of the Hospital de São João/University of Porto Medical School. The project was approved by the Portuguese Authority of Data Protection. The legal representatives of each participant received an explanation about benefits and potential discomforts, through written informed consent, with the information of all the examinations to be carried out during the evaluation, at baseline and in the subsequent follow-up evaluations.

Statistical analysis

Comparisons of continuous variables were performed using the paired sample t-test, and were summarized by means and standard deviations (sd).

Cross-sectional and prospective associations between diet quality and eating behaviours related to appetite from 7 to 10 years-old were measured through linear regression models - regression coefficients and respective 95% confidence intervals [β , 95%CI]. Model 0 represents crude associations. Model 1 was adjusted for maternal sociodemographic characteristics (maternal age and education). Model 2 included those variables from model 1 plus child's sex and z-score BMI at the 7 years-old.

An adjusted cross-lagged analysis (33) was performed to check the direction of the association between diet quality and eating behaviours related to appetite from 7 to 10 years. The cross-lagged model were used since we have two variables of interest measured at two different moments, and we intended to determine the reciprocal relationship, or bidirectional influences between them, as well as to perceive the associations and strength of some variables with the others over time. A Comparative Fit Index (CFI) and a Tucker-Lewis Index (TLI) ≥ 0.90 , and a Root Mean Square Error of Approximation (RMSEA) < 0.06 were used as criteria to support the goodness of fit.

The software used was the Statistical Package for the Social Sciences (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.), and the R® 3.0.1 R language and software environment for statistical computation (version 2.12.1, R Foundation for Statistic Computing, Austria, 2010), package 0.6-3. We considered a significance level lower than 0.05.

Results

Table 1 shows the characteristics of the children included in the study sample, and the respective mothers. Children's BMI increased significantly from 7 to 10 years-old. The HEI score had a slight decrease from 7 to 10 years of age [20.4 (sd = 3.4) vs. 18.6 (sd = 3.3), respectively, $p < 0.001$]. The HEI scores ranged between 9 and 31 points at 7 years of age, and between 10 and 30 points at 10 years of age. The mean scores of the CEBQ sub-dimensions ranged between 2.1 (sd = 0.9) for FR and 3.1 (sd = 0.9) for EF at 7 years of age, and between 2.1 (sd = 0.8) for EOE and 3.2 (sd = 0.9) for EF at 10 years of age (Table 1).

The associations between each CEBQ sub-dimensions score and the HEI score in both directions are shown in table 2. The first set of analyses evaluates the association between the HEI score at 7 years of age and the score of CEBQ sub-dimensions at 10 years of age. In model 2 (considered as the final model) a higher score in the HEI at age 7 showed a significant negative association with SR and FF sub-dimensions score at 10 years [$\beta = -0.039$ (95%CI: -0.067; -0.010) and $\beta = -0.030$ (95%CI: -0.056; -0.005), respectively]. A higher diet quality had no significant effect on the score of the sub-dimensions FR, EF, DD, SE, EOE and EUE at 10 years.

The second set of analyses (table 2) evaluate the association between each CEBQ sub-dimensions scores at 7 years of age and the HEI score at 10 years of age. On one hand, a higher score in the EF sub-dimensions ($\beta = 0.046$, 95%CI: 0.015; 0.076) at 7 years was significantly associated with a higher diet quality at 10 years of age, after adjusting for potential confounders (model 2). On the other hand, a higher score in the FF sub-dimensions ($\beta = -0.033$, 95%CI: -0.061; -0.004) at 7 years showed a negative association with the diet quality at 10 years. No significant effect of the remaining sub-dimensions at age 7 on the HEI at 10 years was observed.

To analyse the direction and magnitude of the association between the eight sub-dimensions of the CEBQ and the HEI, a cross-lagged analysis was performed (Figure 1). The models have a CFI and TLI greater than 0.90 and an RMSEA close to 0, supporting goodness of fit. The tracking, from 7 to 10 years, of the HEI score and the eight sub-dimensions was moderate and statistically significant. A negative association was found in both directions for the FF sub-dimensions, with similar magnitude ($\beta_{\text{standardized}} = -0.033$ compared with $\beta_{\text{standardized}} = -0.030$). The sub-dimensions EF and SR only show association in one direction. A higher score in the HEI at age 7 was therefore associated with lower scores in SR at age 10 ($\beta_{\text{standardized}} = -0.039$), while a higher score in the EF sub-dimensions at age 7 ($\beta_{\text{standardized}} = 0.046$) was associated with higher scores in the HEI at age 10. The remaining models showed no association in either direction.

Discussion

The present study has shown a bidirectional association between the FF sub-dimension and diet quality, as well as a unidirectional association between a higher diet quality at 7 years with a lower SR score at 10 years, and a higher EF score at 7 years, with a higher diet quality at 10 years.

Children with higher enjoyment of food at 7 years of age had a better diet quality a few years later. In previous studies, enjoyment of food has been associated with higher protein-rich (e.g. meat) and nutrient-rich foods (e.g. fruit and vegetables) consumption (34, 35). This may indicate that children with this behavioural trait are more likely to have a diet that meets dietary recommendations. Thus, the enjoyment of food can be seen as a desirable eating behaviour characteristic. Contrarily, other studies have associated enjoyment of food with higher body adiposity (36-38). Therefore, children who score higher in this sub-dimension may benefit from individual nutritional monitoring.

Children following a healthier dietary pattern at 7 years-old were the ones scoring lower in the satiety responsiveness sub-dimension at 10 years. Satiety responsiveness refers to the degree of self-regulation of amount of food intake, based on satiety. These results are in line with previous studies, in which higher scores for this sub-dimension are associated with higher energy-dense food consumption (e.g. sweets), and lower preference for fruit and vegetables (34, 35, 39). The presence of these dietary characteristics may decrease the child's diet quality, especially if parents reward the child's lower consumption of nutrient-rich foods with higher consumption of sweets. In this case, the food counselling to guarantee an adequate nutrient intake is also recommended.

As previously mentioned, the food fussiness sub-dimension is the only one with a bidirectional association with diet quality between 7 and 10 years of age. Higher scores in the food fussiness sub-dimension at 7 years-old were associated with worst diet quality at 10 years-old, and higher scores in the HEI at 7 years-old predicted lower scores in the food fussiness sub-dimension a few years later. Picky eating children are the ones with a low intake of total energy, as well as, total fat, fiber, protein and fruit and vegetables (39-43). Thus, they are less likely to meet dietary recommendations.

Several factors might contribute to the development of eating habits that would reduce children's food fussiness. Social factors, such as higher parental education, have been associated with higher consumption of healthy foods (44-46). Environmental factors have also been shown to be fundamental to the development of eating habits. Children tend to learn by imitating their role models, who are usually the parents (47). Therefore, it is important for parents to create a healthier eating environment, since they control what is

purchased for the child, to shape their eating habits (41, 48). Also, early life factors seem to influence the development of FF, as it has been associated with reduced duration of breastfeeding and early introduction of food (49). That being said, it is important to create strategies to counteract this eating behaviour. Studies suggest that parents should allow the child to help prepare and cook healthy foods, to gain a greater curiosity to taste the dish and to try to mimic the eating behaviour of parents (50, 51). Also, consistently greater food variety and availability at home and greater persistence with food consumption over time may be beneficial (52). Foods that are most often rejected by fussy children should be repeatedly offered to the child on different occasions, encouraging them to taste (53).

In this study, children's diet quality was explored using an index (HEI), and we observed that although the score of the index has decreased from 7 to 10 years, the results support a moderate tracking. The better the diet quality at age 7, the better the diet at age 10. The presence of tracking may be related to the fact that the eating habits developed early in life influence food choices in subsequent years, despite eventual changes throughout the child's growth (54). In this way, it is essential to establish healthy eating habits since the early stages.

Significant correlations were found for all eight CEBQ sub-dimensions between 7 and 10 years of age. This indicates that children's appetitive traits are relatively stable throughout childhood. Given the developmental changes that can occur between 7 and 10 years, the main assumption would be that changes in the appetitive traits may occur during this period. However, we observed that the children tend to keep their initial position, which indicates that they have specific ways of interacting with the food environment, and these characteristics may persist over time, as previously hypothesized (55).

The main strengths of this study are its prospective design based on a relatively large and representative sample of children followed from birth in the context of a prospective cohort, with a high participation rate. This allows for more detailed measurements of dietary habits and eating behaviour over time, as well as greater control for a wide range of potential confounders. However, as in other infant feeding studies, both FFQ and CEBQ have been subjectively assessed based on parental reporting, which may lead to misinterpretation and bias of social desirability. In the case of FFQ, parents may have underestimated the consumption of unhealthy foods or overestimated the consumption of foods generally recognized as healthy. If this has happened, the associations studied may be underestimated. However, as the FFQ has been previously validated, is not expected that the associations have changed (27). Concerning the CEBQ, it is important to note that its sub-dimensions showed good internal reliability as well as stability over time and good

psychometric properties in various populations around the world, including the study population (31). Moreover, self-administered questionnaires often have low response rates, as occurred in the present study concerning the CEBQ. Although it was possible to retrieve missing data in questionnaires (around 3%) with more than 50% of completed items. Finally, the results of the present study cannot be generalized beyond the considered ages, as the relationship between food quality and eating behaviour may be different at different stages of childhood. Feeding may be under parents' supervision early in life, while in later stages children may have greater control over what they really eat or not, as well as more out-of-home meals.

Conclusions

A bidirectional inverse association was found between children's diet quality and food fussiness and a higher diet quality at 7 years of age were associated with lower satiety responsiveness a few years later. Moreover, children having higher enjoyment of food at 7 years of age were the ones with a higher diet quality at 10 years of age. Although there is a general decrease in the diet quality from 7 to 10 years, it is clear that there is a tracking. Thus, given this mutual influence of diet quality and food fussiness, and the unidirectional associations between satiety responsiveness and enjoyment of food and diet quality, this study shows the importance of implementing strategies that reverse these associations early, making the first years of life a better time to intervene in the acquisition of eating habits and behaviours.

Acknowledgments

The authors gratefully acknowledge the families enrolled in Generation XXI for their kindness, all members of the research team for their enthusiasm and perseverance and the participating hospitals and their staff for their help and support. The authors acknowledge the support from the Epidemiology Research Unit (EPI-Unit: UID-DTP/04750/2013).

Financial support

Generation XXI was funded by the Health Operational Programme – Saúde XXI, Community Support Framework III and the Regional Department of Ministry of Health. It was supported by the Calouste Gulbenkian Foundation, by FEDER from the Operational Programme Factors of Competitiveness – COMPETE and through national funding from the Foundation for Science and Technology – FCT (Portuguese Ministry of Education and Science) under the projects "Appetite regulation and obesity in childhood: a comprehensive approach

towards understanding genetic and behavioural influences” (POCI-01-0145-FEDER-030334) and “Appetite and adiposity - evidence for gene-environment interplay in children” (IF/01350/2015 - Andreia Oliveira), and by the PhD grant RH/BD/92389/2013 (SV).

Conflict of Interest

None.

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Table 1. Participants' characteristics at baseline and follow-ups at 7 and 10 y of age

	Evaluation			
	Baseline	7 years	10 years	p-value
Maternal age (years), mean (sd)	30.0 (5.1)	-	-	
Maternal years of education, mean (sd)	11.3 (4.3)	-	-	
Girls, n (%)	1899 (49.0)			
Child's practice of Structured Physical Exercise, n (%)	-	3306 (85.5)	2486 (64.1)	<0.001
Child's BMI, mean (sd)		17.0 (2.4)	18.7 (3.4)	<0.001
Healthy eating index score, mean (sd)		20.4 (3.4)	18.6 (3.3)	<0.001
Children's Eating Behaviours, mean (sd)				
Food Responsiveness		2.1 (0.9)	2.3 (0.9)	<0.001
Enjoyment of Food		3.1 (0.9)	3.2 (0.9)	<0.001
Satiety Responsiveness		2.8 (0.8)	2.7 (0.7)	<0.001
Slowness in Eating		3.0 (0.9)	2.7 (0.9)	<0.001
Desire to Drink		2.3 (1.0)	2.2 (0.9)	<0.001
Food Fussiness		3.0 (0.8)	3.0 (0.8)	0.132
Emotional Over Eating		2.0 (0.9)	2.1 (0.8)	<0.001
Emotional Under Eating		2.6 (1.0)	2.5 (0.8)	<0.001

BMI, body mass index; sd, standard deviation

p-value are calculated by paired sample t-test; * possible range: 1 to 5

Table 2. Prospective associations between the Healthy Eating Index (HEI) score at 7 and 10 years and CEBQ sub-dimensions at 7 and 10 years

HEI at 7 and CEBQ sub-dimensions at 10y			
Sub-dimensions	Model 0 β (95%CI)	Model 1 β (95%CI)	Model 2 β (95%CI)
Food Responsiveness	-0.008 (-0.036;0.019)	0.002 (-0.026;0.031)	-0.003 (-0.031;0.025)
Enjoyment of Food	0.020 (-0.007;0.047)	0.024 (-0.004;0.052)	0.025 (-0.002;0.053)
Satiety Responsiveness	-0.032 (-0.059;-0.004)	-0.038 (-0.067;-0.009)	-0.039 (-0.067;-0.010)
Desire to Drink	-0.019 (-0.049;0.012)	0.010 (-0.021;0.041)	0.009 (-0.022;0.040)
Slowness in Eating	0.016 (-0.011;0.042)	0.016 (-0.012;0.043)	0.017 (-0.010;0.044)
Food Fussiness	-0.032 (-0.057;-0.006)	-0.031 (-0.058;-0.005)	-0.030 (-0.056;-0.005)
Emotional Over Eating	-0.017 (-0.046;0.013)	-0.003 (-0.034;0.027)	-0.009 (-0.039;0.021)
Emotional Under Eating	-0.016 (-0.046;0.014)	-0.024 (-0.055;0.008)	-0.023 (-0.055;0.008)
CEBQ sub-dimensions at 7 and the HEI at 10y			
Sub-dimensions	Model 0 β (95%CI)	Model 1 β (95%CI)	Model 2 β (95%CI)
Food Responsiveness	-0.001 (-0.030;0.027)	0.010 (-0.018;0.039)	0.005 (-0.025;0.036)
Enjoyment of Food	0.026 (-0.003;0.054)	0.045 (0.017;0.074)	0.046 (0.015;0.076)
Satiety Responsiveness	-0.009 (-0.037;0.020)	-0.010 (-0.038;0.018)	-0.006 (-0.035;0.024)
Desire to Drink	-0.027 (-0.055;0.002)	-0.008 (-0.037;0.021)	-0.009 (-0.038;0.020)
Slowness in Eating	0.014 (-0.015;0.042)	0.018 (-0.010;0.047)	0.027 (-0.003;0.057)
Food Fussiness	-0.033 (-0.062;-0.005)	-0.034 (-0.062;-0.006)	-0.033 (-0.061;-0.004)
Emotional Over Eating	-0.011 (-0.040;0.017)	-0.003 (-0.031;0.025)	-0.005 (-0.034;0.023)
Emotional Under Eating	-0.013 (-0.041;0.016)	-0.015 (-0.043; 0.013)	-0.014 (-0.042;0.014)

CI, confidence interval; CEBQ, Children's Eating Behaviour Questionnaire; Statistically significant associations are shown in bold-type

Model 0: unadjusted, model 1 adjusted for maternal sociodemographic characteristics, model 2 adjusted for maternal sociodemographic characteristics plus child's sex and BMI at 7-years evaluation.

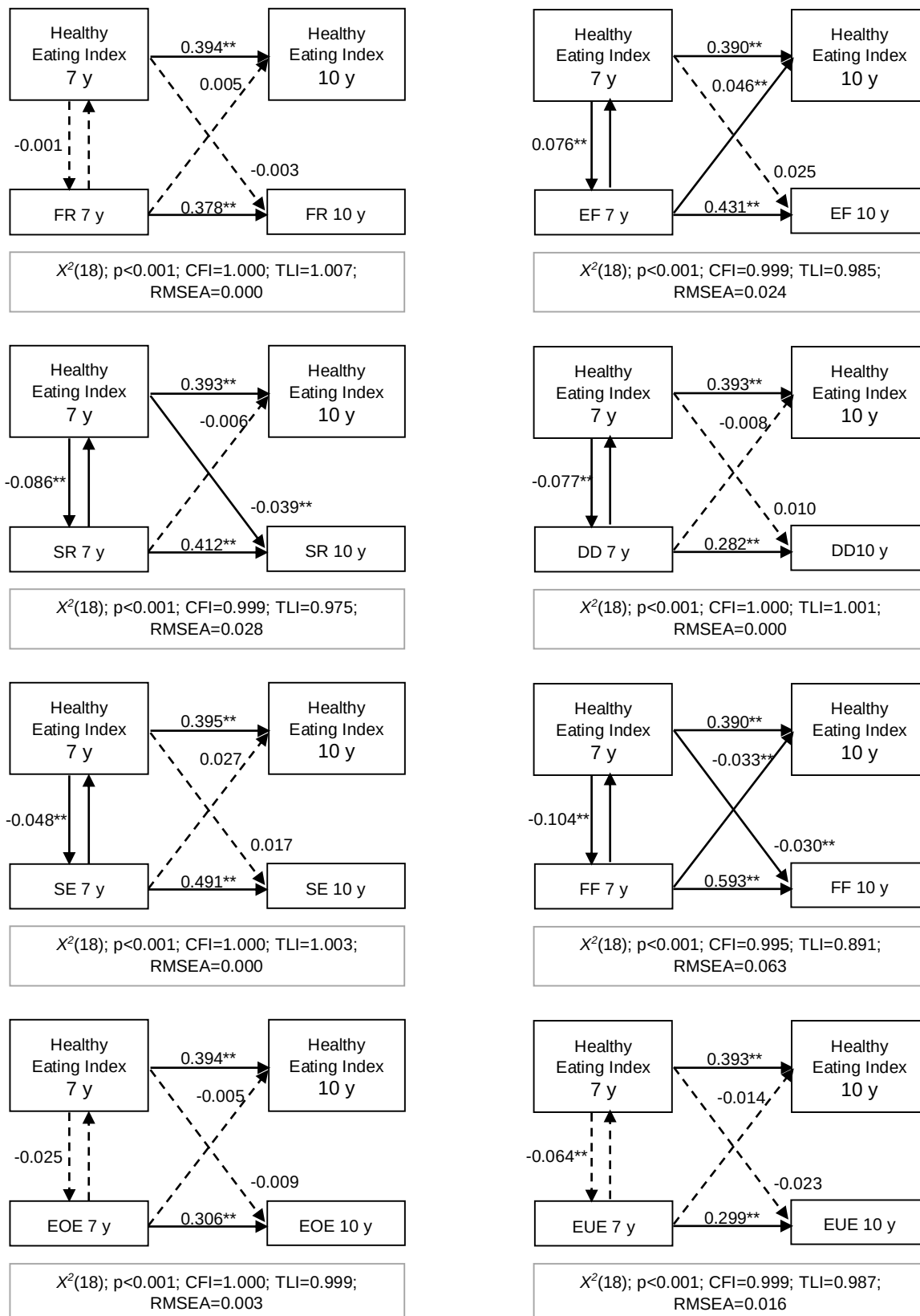


Figure 1 Cross-lagged models for the associations between the score of the healthy eating index and the score of each CEBQ sub-dimensions at 7 and 10 y of age. All values represent standardized β -regression coefficients. All association were adjusted for maternal sociodemographic characteristics, child's sex and BMI at 7-years evaluation $**P<0.001$. CFI, comparative fit index; RMSEA, root mean square error of approximation; TLI, Tucker–Lewis index; FR, Food Responsiveness; EF, Enjoyment of

Food; SR, Satiety Responsiveness; DD, Desire to Drink; SE, Slowness in Eating; FF, Food Fussiness; EOE, Emotional Over Eating; EUE, Emotional Under Eating.

Discussion

In this thesis, determinants of diet quality tracking and its association with eating behaviours related to appetite were studied using a prospective approach. Overall, the results suggest the existence of dietary tracking between early and late childhood, influenced by sociodemographic and maternal characteristics, as well as an association of diet quality with some sub-dimensions of eating behaviour.

An overall decrease in children's diet quality was described from 4 to 10 years. This decline may be due to increased consumption of animal protein sources, soft drinks and sweets, as well as decreased consumption of dairy products and cereals and potatoes. However, the results support the existence of eating habits tracking, that is, the better the diet quality at 4 years old, the better it will be a few years later. This association results from the fact that the eating patterns formed at the beginning of life may continue to influence the eating habits of children years later. This is in line with the results of previous studies also conducted in the Generation XXI cohort, where a tracking level was observed from 4 to 7 years, and where some level of stability of eating habits throughout childhood was also described (136).

Maternal education and eating habits were independently associated with better diet quality at 7 years. Indeed, previous studies have also linked children's healthier eating habits with higher maternal education and better dietary intake (60, 137-140). This thesis shows that the maternal diet is one of the most important factors associated with infant diet quality. Children learn about food through their direct eating experience and also by observing the eating behaviour of their peers, and especially their parents (6, 141).

Prenatal risk factors for the development of obesity, namely pregnancy weight gain(109), gestational diabetes(108), duration of breastfeeding (108) and smoking during pregnancy (142) may also be associated with children's dietary quality. However, the results from this thesis found no significant associations between diet quality and early life factors. The socioeconomic environment, as well as maternal characteristic, are the main significant determinants of children's dietary quality, at these ages. In a previous study conducted in a twin birth cohort among young children's, the shared environmental influences are described as the predominant determinants of children's dietary intake (143). The mother's weight status, also previously identified as influencing other child's eating habits, does not seem to have any statistical association with children's dietary intake (144).

A bidirectional association was found between higher scores in the 'food fussiness' sub-dimension and diet quality. That is, the higher the sub-dimension score at 7 years, the worse the quality of the diet at 10 years, and the higher the healthy eating index score at 7 years, the lower is the sub-dimension score at 10 years. Previously, a higher 'food fussiness'

sub-dimension score was associated with lower consumption of fruit, vegetables and meat (91). Children with this appetitive traits seem to have a lower total energy, fat and protein intake compared to children who are not picky eaters (91). The presence of shared and structured family meals has been suggested as a strategy for reducing the food fussiness trait (145). From early life, children should be exposed to a variety of foods, and parents should make healthy foods available at home, repeatedly exposing the child to one food at a time. Parents are responsible for modelling children's eating behaviour, and children indeed learn by imitating models, so a variety of strategies for improving eating habits should be applied by parents.

Children with a higher highest 'enjoyment of food' at 7 years had a better dietary quality at 10 years. The 'enjoyment of food' sub-dimension was also previously associated with a higher intake of protein and nutrient-dense foods, fruits and vegetables demonstrating that the presence of this trait can be a benefit to children's diet quality (121, 146). However, this sub-dimension has also been linked to weight (118, 119), body fat percentage (147) and obesity (120) in children, perhaps due to a higher overall food intake and consequently higher energy intake. These children might particularly benefit from individual nutritional counselling.

Better diet quality at 7 years predicts lower satiety responsiveness score at 10 years. A higher score in this sub-dimension has been associated with higher consumption of sweets and chocolates and lower preference for fruits and vegetables, which in turn may impair the quality of children's diets (121, 146). Notwithstanding, higher scores for this sub-dimensions have been associated with a lower risk of overweight (117).

Limitations and Strengths

Some limitations of this thesis should be discussed and, consequently, the results should be interpreted in light of them. Previous research has shown difficulties in collecting data on children's food intake (148). Child feeding information was reported by parents through the FFQ in a face-to-face interview, who may not be aware of all food offered to children when they are with other caregivers or at school. Since it is only from older ages that children are able to self-report their eating habits, and since until then they find it more difficult to estimate portion sizes and have more limited cognitive abilities, parents are often used as substitutes for their children in reporting, as in the present study (148, 149). However, in a subsample of children belonging to the same cohort, nutritional information was also collected through 3-day food diaries (2 weekdays and 1 weekend day) and

compared with data obtained from the FFQ, which allowed to determine the validity of the results (150), and shows that the healthy eating index was assessing a better diet quality. Thus, for this analysis two of the most commonly used food collection methods were used, the food diary and the FFQ, which allowed the reduction of reporting errors (151).

Given that both CEBQ and FFQ were subjectively assessed based on parental reporting, they may be subject to misinterpretation and social desirability bias. In the FFQ, this bias may have resulted in an underestimated reporting of unhealthy food consumption (such as high energy density foods), or an overestimated reporting of healthy food consumption (such as fruit and vegetables). If this happens, the associations obtained may be underestimated. However, as the FFQ has been previously calibrated, is not expected that the associations have changed (150). In the case of CEBQ, its dimensions demonstrated good internal reliability, stability over time and good psychometric properties in various populations, including the study population (81).

Strengths of this study are the use of a relatively large and representative sample of children from a regularly assessed, high-participation population-based birth cohort, as well as their longitudinal design. This allows a time sequence of various exposures as well as tracking of food intake and appetite-related eating behaviours. There is also greater control of potential confounders.

Conclusions

Overall, the quality of food intake decreases as children grow older. However, some level of diet tracking was observed between 4, 7 and 10 years of age, and the higher the diet quality at earlier stages, the higher at older ages. Sociodemographic factors and maternal behaviours influence healthy eating habits, as higher maternal education and especially a healthier maternal diet increase the quality of the child's diet. A bidirectional inverse association was found between children's diet quality and food fussiness and a higher diet quality at 7 years of age were associated with lower satiety responsiveness a few years later. Moreover, children having higher enjoyment of food at 7 years of age were the ones with a higher diet quality at 10 years of age. It may be concluded that children who follow an unhealthy eating pattern early in life continue to maintain this trend and exhibit disordered eating behaviours years later. Early interventions involving less-educated mothers and encouraging healthy eating habits are very important, as eating habits and behaviours are defined early in childhood and tend to persist into adulthood. It is important to develop strategies that promote children's health and control its inherent behaviours.

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